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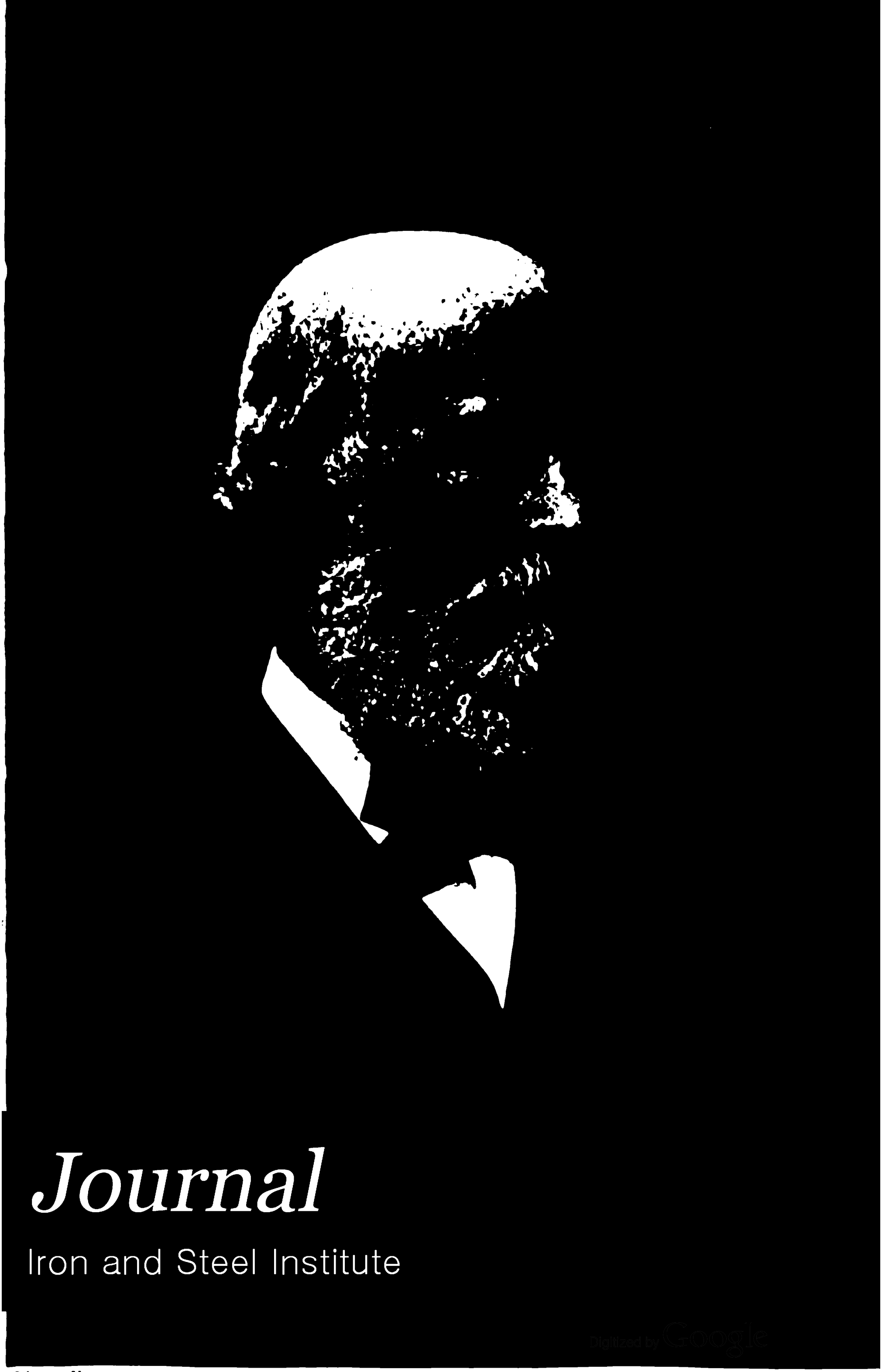

Journal

Iron and Steel Institute

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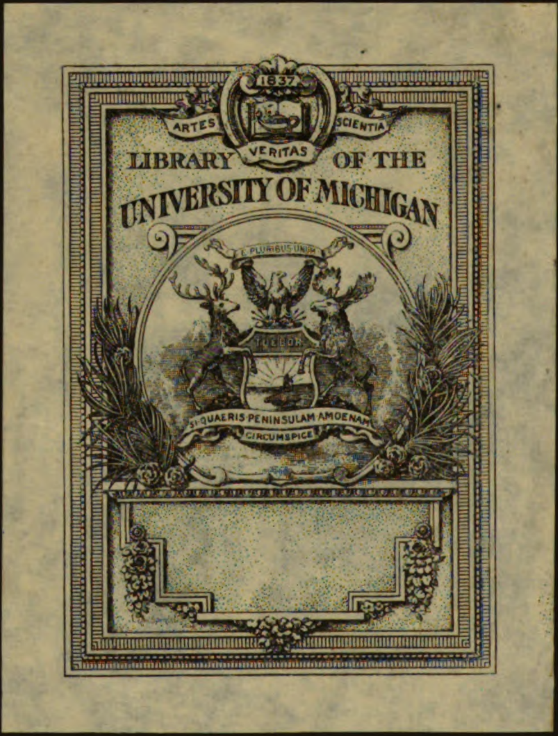

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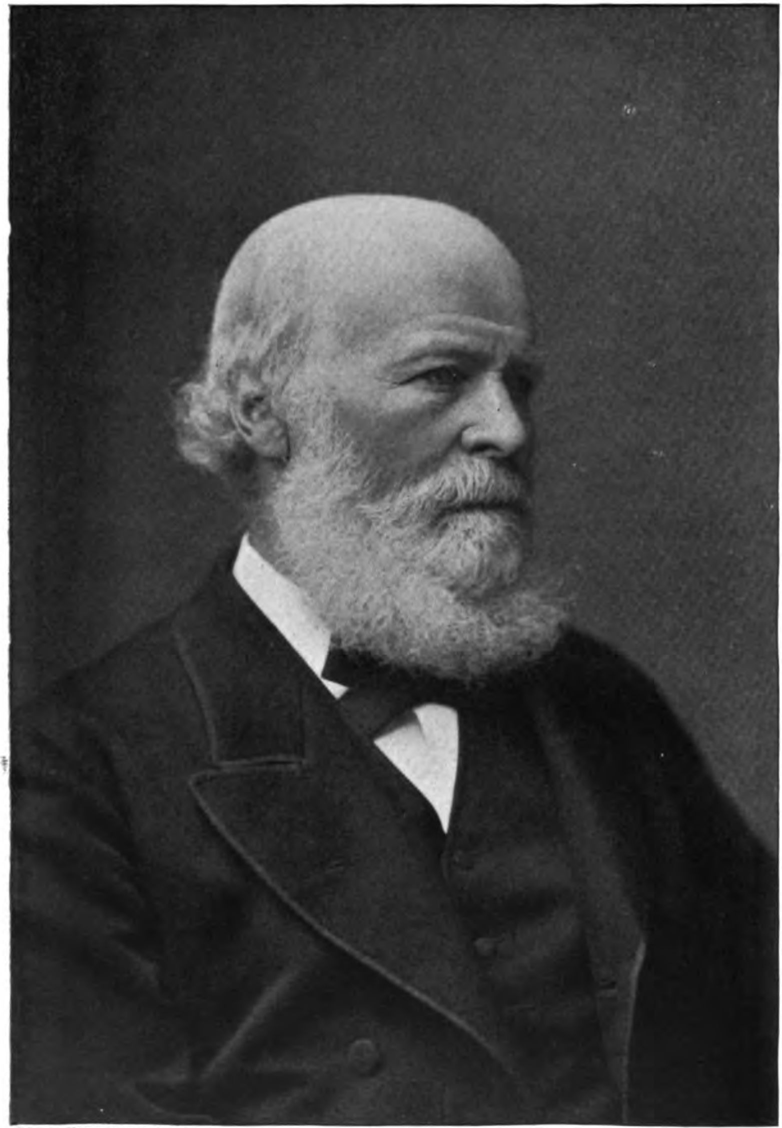

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SIR LOWTHIAN BELL, BART.

PRESIDENT 1873–75

Died December 21, 1904

THE JOURNAL

IRON AND STEEL INSTITUTE.

VOL. LXVI.

EDITED BY

BENNETT H. BROUGH,

LONDON:
E. & F. N. SPON, LIMITED, 125 STRAND;
NEW YORK: SPON & CHAMBERLAIN, 123 LIBERTY STREET.
SOLD ALSO AT THE OFFICES OF THE INSTITUTE,
28, VICTORIA STREET, LONDON, S.W.
1904

SIR [illegible]

No. II 1904

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Printed by Ballantyne, Hanson & Co.
At the Ballantyne Press

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THE

IRON AND STEEL INSTITUTE.

SECTION I.

MINUTES OF PROCEEDINGS.

AMERICAN MEETING.

The Autumn Meeting of the **Iron and Steel Institute** was held in the Ballroom of Sherry's, New York, on Monday evening, October 24, and in the Ballroom of the Hotel Astor, on Wednesday, October 26—Mr. **Andrew Carnegie**, President, in the Chair.

Reception of the Institute.

Mr. **Charles Kirchhoff**, Chairman of the Executive Reception Committee, opened the proceedings, and said: This being the gateway of our country, New York is naturally the first of the places that receives admiration and occasional criticism. We try to dodge the latter, wince under it, but secretly we appeal for the former. No one is, however, better qualified to waive aside the one and attract the other than our Acting Mayor, the President of the Board of Aldermen, whom I now have the honour to introduce to you, the Hon. Charles V. Fornes.

The **Acting Mayor of New York** (Hon. C. V. Fornes) then welcomed the Institute. He said: Your Chairman has fitly said that New York is the gateway of our country. It affords me pleasure, and I deem it a great privilege, to join you in spirit at the commencement of your journey. When we enter upon a journey we are generally bidden God-speed, a good time, happiness, and a safe return, and with this I greet you. In the absence of the Mayor of New York I feel it a high honour to take his place on this occasion, and to extend to you on behalf of the citizens of the Metropolis of America a most hearty welcome. Words of this nature, doubtless, most of you have listened to frequently, but to me it is a special pleasure to have the opportunity of extending the welcome to such an important and renowned an organisation. Nearly fifty years ago you formed yourselves into a Society, and gave the deepest and most studious thought to unravelling the mysteries of Nature, and in bringing them under subjection for the good of mankind. It is indeed an occasion to be considered memorable when there are gathered from almost all parts of the world men whose patriotic devotion have brought the results of their genius to carry forward and bring into subjection the forces of Nature. That being so, in what city of the world could a welcome be expressed more fitly than in the City of New York, which, doubtless, is the greatest customer for your inventions and of your studies in iron and steel. Those of you who are not well acquainted yet with the great works which the City of New York has undertaken—one of which is the beginning of a new era in the method of travelling, viz., the new subway which will be opened on Thursday next—will feel that your cousins on this side of the Atlantic have not been asleep, but have deeply appreciated the obligations they are under to your Institute for having provided them with the means for the successful building of the subway, and of the immense bridges which join the various parts of Brooklyn and Manhattan. All these works have been the result of your life studies which have enabled them to be accomplished. Let us hope that while the City is extending to you its welcome, it at the same time can impress upon every member of the Institute the fact that we Americans have taken every advantage of what Nature has bestowed on our land, and turned it, not only to the advantage of our own country, but of the whole world. If you return with these thoughts, we think your mission will have effected its purpose. No longer, as only a century ago, does one nation behold with the spirit of jealousy the advantage and the progress of another; no longer does that selfish spirit exist which prompts one who has discovered something to guard it jealously for fear that his neighbour may receive the glory which he thinks belongs to him. No longer do the people of Great Britain, France, and Germany look with envy to America or to each other, but they feel that by one nation advancing and reaching the higher ideal of what man is capable of accomplishing, all nations will feel the common benefit of such achievements. We hope the hospitality we extend to you to-night will add another link to that bond of friendship, and to that bond of scientific research which your Institute has carried on, perhaps to a more successful degree than any other organisation.

Mr. KIRCHHOFF said: It was only the turbulent Atlantic which prevented the President of the Reception Committee, Mr. John Fritz, from going to England to give personally to you the invitation which you have so kindly accepted. I need hardly introduce Mr. Fritz to you because he is already one of yours; you have conferred upon him the greatest distinctions in your gift, and one that has made us all very proud. It is not necessary, therefore, that I should introduce to you our—and your—Uncle John Fritz.

Mr. JOHN FRITZ, Honorary Member, said: It is a source of much pleasure to meet you here this evening and say "Welcome," a word that comes from the fulness of my heart. In the name of the American engineers I bid you welcome, one, each, and all, to this our country, of which we feel most justly proud. Everywhere in this broad land, wherever there is an engineer, you will find the hand of fellowship, and in its strong grasp feel the friendship that has grown out of our similar pursuits. Hard and perplexing toil has welded us into one great family, striving ever for the unselfish advancement of that still greater family, the whole of mankind. Where has there been a greater liberator than the engineer? With every labour-saving device shackles have been struck from the hands of toiling humanity, the engineer has conquered time and space, and the full fruition of his victory is shared by all. How incomparably small seems the winning of a few paltry acres that are held for the chosen few by constant vigilance and the force of arms. The engineer, in placing the forces of Nature under man's control, has quickened civilisation and commerce, furnished means for supplying the dearth of one nation from the fulness of another, converted the wilds of Nature into fertile fields, and made happy homes for millions. It does me good to welcome to our shores the Iron and Steel Institute, a Society whose banner from its first raising has always stood in the front rank of progress, and has guided the way to heights the boldest had scarce dared hope to climb. A Society of unselfish interests, whose membership comprises the ablest engineers and scientists, chosen without respect to nationality, from all parts of the world; a membership whose sole object is the advancement of the most important of all human industrial institutions, the manufacture of iron and steel. To the able and far-sighted men who founded this Institute belongs the gratitude of the civilised nations of the world, for their sole object was the common good, and their only reward the satisfaction of an unselfish devotion to the science of metallurgy. I cannot but think that every true man will respect those who worked so assiduously for the improvement of an article of such prime necessity to the civilised world. Let me ask: Is there a higher world's calling, a more noble profession, or one that mankind is more deeply indebted to than the metallurgy of iron and steel? Yet how few people know or even think of the debt they owe to workers in this invaluable field of science. Few have had the occasion or opportunity to understand or appreciate the exacting labour of years, with its many tribulations and distressing accidents that occurred in the introduction and advancement of the processes of steel-making, but only view it in its fully consummated shape of to-day. Yet with all its difficulties—and they were many—it is the most important branch of manufacture in the domain of human activity, requiring courage, endurance, and a varied talent, attributes which make the engineer of the highest development. In the beginning of the twentieth century we find the engineer the most important personage upon the world's stage, whether the drama be that of peace or war. It is to be hoped that before its close the world will recognise his work, and accord to him the position most justly his. It affords me great pleasure to see you here to-night so many thousand miles from home; and yet, at home in our midst, for it is these meetings that not only cement the hand but the heart from which springs one head to guide and lead to the highest goal. It was by combining our efforts that we have won the progress of the world. Let us further combine our efforts that we may stamp our impress upon the nations, and striving always for purer and higher things, do still more for mankind than we have done for metals. It is by unity of purpose and united energies that all great ends are achieved. Let us then draw closer in our relations and intercourse, aiming to make the engineers one society, with a single aim and a thousand pursuits. We, in America, have already taken steps towards this most desirable end, and through the munificence of your President, shall soon be gathered together under one roof. This union will bear fruit, and we shall, in the years to come, find its weight in the scale of national affairs. But it is still further for you and we to go, joining hands across the seas, and throwing our united weight into the world's great balance for its own greater good. I ask you to pardon me for a brief retrospect. Looking back upon sixty odd years of increasing toil and activity in the iron and steel industry, which at times awakens anxious questioning as to whether we have gone too fast in this fierce race of manufacture, I feel that we owe much to the efforts of this Institute, for while commercialism struggles for larger outputs you, gentlemen, have always stood with steadfast eye watching the quality, and always striving for greater heights. It is you who have always recognised the awful importance of the very highest quality in a material so universally used, that we may almost say the life of the world to-day hangs on a bar of steel. The fraternal feelings already existing between us augurs well for the hope that, through our engineering societies, nations may be drawn into closer bonds, and, by our united efforts, all flags entwined in an everlasting emblem of peace. And fast bound to earth with the word "Engineer" may this be his glory and the crowning glory of the twentieth century. I avail myself of this opportunity of thanking you from the depths of my heart for the honour you have conferred upon me, which is far beyond my deserts.

Mr. KIRCHHOFF said: When Mr. Carnegie was President of the Reception Committee of fourteen years ago, he spoke of this country as "the country of firsts," and he emphasised it by a number of examples. Now, we have not quite given up our ambition in that direction, and we are looking to some of our men to justify that ambition. One of them, one of our great iron and steel masters of the younger school, is the gentleman whom I wish to introduce to you, the President of the American Institute of Mining Engineers, Mr. James Gayley.

Mr. JAMES GAYLEY (New York) said: It is my great privilege, on behalf of the engineers and metallurgists of this country, to speak to you on the occasion of your second visit the kindly words of "welcome," and under the sacred name of "guests," we rejoice to welcome you again after an absence of fourteen years. We have anticipated your coming with keen pleasure, for we have the most pleasant recollections of your first visit. Your President, who, in 1890, was the chief of hosts, becomes in turn the chief of guests. In choosing him—an American citizen—to preside over your Institute, you have not only honoured one who has contributed so much to the metallurgy and development of iron and steel, but who is recognised all over the world as perhaps one of the greatest contributors; but we interpret this choice to have a deeper significance, in that it recognises in a graceful way that, as nations, we are more closely akin. Your Institute represents technical attainment and progress in metallurgy in an age which can be most properly designated as the age of steel, and your achievements in that realm are recognised as having contributed most generously and liberally to the development of that age. Inspired by a profound knowledge of the art, you have consecrated your labours to perfecting the various processes and the products in the great industry which you represent, and thereby have conferred a blessing on the world. When we consider the great development of our own country, we recognise that it is the working out, on a magnificent scale, of ideas which, although brought to perfection in many cases by us, originated nevertheless with you, and we believe that the work and achievements of one have been mutually helpful to the other. In every branch of our industry we acknowledge our indebtedness to the engineers and metallurgists of Great Britain. At a time when we were beginning our industrial development we recognised that they were past masters in the useful arts, and we unhesitatingly appropriated all that we considered of value and adaptable to our needs. In return we have given to you all that it was possible to give, viz., the records of our practice in bringing those processes to a high state of perfection, in a country directing all its energies to industrial development; and in looking back over a period of thirty years we realise, as measured by results, that in utilising your inventions and experiences we have built on a foundation sure and substantial. In your published records you have given with wonderful generosity the results of your best practice and experience These records have not only enriched the literature of manufacturing, but contributed vastly to the world's progress; and we, in turn, have endeavoured through the transactions of our Institute, and in the same spirit of liberality, to present to you our records of processes and practice. In visiting the various works in this country you will no doubt find much that is new and valuable, for since your last visit we have made great progress in practically every line of manufacture. On the occasion of your last visit your President referred to the fact that for the first time this country had surpassed Great Britain in its output of pig iron; since then we have doubled that output, and the development made in this and other branches of this industry is far beyond anything that was contemplated at that time; and this represents, not only the measure of our progress, but also, and fittingly, the measure of our welcome to you. We have, as I have said, appropriated everything of yours which we considered of value, and we invite you in the same neighbourly spirit to appropriate all that you find of value among us. The greatest advantage to be gained for all of us is in the free exchange of experience obtained under different conditions and in localities far removed from each other; for the free interchange of thoughts among people who have devoted their lives to a great industry becomes of universal value. Notwithstanding our own great progress we are proud to greet you as first citizens of the commonwealth of industry. We wish—and it is our dearest wish—that on the occasion of this visit we shall find that the friendships formed on the first visit between the engineers and metallurgists of Great Britain and America shall not only continue, but that new and lasting ones shall be formed on this visit; and with this hope we say to you "Welcome," yea, "thrice welcome!"

The **President**, in reply, said: If all the appointments of his Honour, the Mayor of New York, are as good as the appointment of the substitute he has sent us to-night, I believe some very strict Republicans might be induced to vote for him for a second term. On behalf of the Iron and Steel Institute, I beg to return grateful thanks to you, as representing the City of New York, for the exceedingly cordial welcome which you extend to us. Its warmth does not surprise us, for the Institute is no stranger to American hospitality. Fourteen years ago, as Mr. Gayley has said, we visited your land, and received a welcome that never can be forgotten. Many then present are again your guests to-day. Among these, I shall be pardoned for mentioning our distinguished Past-Presidents, Sir James Kitson, Bart., Mr. E. Windsor Richards, Mr. E. P. Martin, and Mr. W. Whitwell. I have recently been reading the volume in which record is made of that ever-memorable visit. I am sure you will welcome Sir James Kitson back here. Sir James was the President then, and he has since become one of the important "connecting links" which serve to bind closer together the two branches of our English-speaking race. He gives strong expression to this international feature in the last paragraph of his introduction to the volume containing a full and most valuable record of that ever-memorable visit. It closes with these words: "The friendships formed, and the international courtesies bestowed, are such as will confer lasting pleasure and national benefit as long as their record endures." Let us hope that this, our second visit, will not be less fruitful in that glorious work to which the Mayor, Mr. Fritz, and Mr. Gayley have referred, viz., in drawing together in closer bonds, not only the members of our own race, but all the members that represent the nineteen countries from which we draw our membership. Man in his time plays many parts. From that same introduction of Sir James Kitson to the first visit, I read that it was my privilege to deliver the speech of welcome, as Mr. Gayley has done to-night. On this evening I receive it as President of the Institute. Listening to your welcome, it occurred to me that, if, as President, I should be called upon to write an introduction to the forthcoming record, Sir James has already furnished me with exactly what I should have to say. He notes that "Mr. Andrew Carnegie, on behalf of the American Iron and Steel Trades, gave the address of welcome at our first meeting, which was held on the 1st of October in Chickering Hall, New York. His eloquent address was most cordial" (I am quoting Sir James), "nay, even affectionate, in its warmth of expression. He promised that every mine, every manufactory, and every workshop would be absolutely open for inspection, and, further, that any information asked for would be cheerfully and frankly supplied." Sir James continues: "I repeat this in order that I may acknowledge, which I do in all sincerity, how fully and completely this undertaking was fulfilled, and I would express, on behalf of the Institute, our grateful thanks for the 'open door,' and for the information so generously given." Now we of the Institute on our arrival in New York are again presented with the "open door," and we thank you. Mr. Gayley has just told you we have appropriated from you everything we could find. Now Mr. Gayley asks you, gentlemen, to appropriate everything there is in this land that can be of benefit to you. He has made a wonderful statement. We were amazed (I speak now as President of the Institute) at our and your extraordinary progress. Mr. Gayley says that the pig iron production has doubled. That of Bessemer steel has much more than doubled. And here is the most remarkable of all industrial facts as far as I know. Open-hearth steel has increased elevenfold since you were here before. It was in 1890 half a million tons; and it was in 1903 nearly six million tons. In ten years (1890 to 1900) your country has added thirteen and a half millions of population. It is increasing at a faster rate to-day. The national wealth has risen from sixty-five thousand millions to ninety-four thousand million dollars, and the foreign exports have increased threefold. No wonder to you of America that we of the Institute come here to see for ourselves and to study such portentous growths. In America that growth in steel has been accomplished in the face of an increase in Britain, France, and Germany. The growth of America has not lessened the product of any country, because such is the demand of the world for steel that the question is not, in my opinion, what markets a steel-making country will have in the future, but how the wants of the world for steel are to be supplied. Certainly I think, with Mr. Gayley, a great authority on this point, that we must make further discoveries of iron ore if we are to be able to meet the wants of the world in fifty years with steel as cheap as it is to-day. Now, gentlemen, you will permit me as President of the Institute to note that our members from Britain have one source of credit and satisfaction in seeing your progress—we cannot cease to remember that it is through the inventions of the old land that you have been enabled to make this extraordinary growth—it is to Neilson and Cort; it is to Bessemer, to Siemens, and to Thomas and Gilchrist that you are indebted for your success. We hope you Americans, when you are disposed to congratulate yourselves on your progress, will at least remember that you owe to the dear Motherland the means of that success. The cosmopolitanism of this Institute is a note that has been struck by his Honour the Deputy Mayor, and also by Mr. Gayley. We are all very proud of this Institute. It has no narrow traits. It draws its members from nineteen of the principal countries of the world. No invention, no improvement in any works in any of those countries but the record of it, the description, and all the statements are brought and read in public at the Meetings of this Institute. This is a feature which charms me more than any other connected with this Institute; and in all my experience. I know of no institution that equals the Iron and Steel Institute in this respect. I cannot help thinking that if the statesmen of one quarter of the countries which we represent, or even less, would come together as we do and discuss their problems in the spirit of brotherhood and goodfellowship that prevails with us, the world would soon be a happier and a better world. But, members of the Institute, let us continue on that high plane of action; meeting together, comparing notes, and telling everything that we know to each other, welcoming every improvement; applauding every success, by whatever nation accomplished, and all this without the slightest trace of any heart-burnings at another's success. Mr. Mayor, Mr. Fritz, and Mr. Gayley, we thank you again for your welcome, and for the kindly feeling you have expressed. Your welcome, believe me, is very deeply appreciated indeed by every member of this Institute.

PRESENTATION OF THE BESSEMER GOLD MEDAL.

Sir JAMES KITSON, Bart., M.P., Past President, then presented the Bessemer gold medal to Mr. Carnegie. He said: Ladies and gentlemen, you will all probably remember the play of the "Mikado." The Prime Minister of the monarch found himself in a very great difficulty, being a pluralist of offices. He was not only the Prime Minister, but he was also the Lord Chancellor, and the Lord High Executioner; and, therefore, when a great ceremony had to be performed upon himself he found it extremely difficult to carry the sentence into execution. Well, this is the first time in the history of our Institute that the President of that Institute has been voted the gold medal "for distinguished services to the iron and steel trade," during his term of office. Consequently it has fallen to me, who was the President of this Institute when fourteen years ago it made its memorable visit to the United States—it has fallen, not, I hope, inappropriately, to me, to confer, on behalf of our Institute, the gold medal of that Institute upon our President, Mr. Andrew Carnegie. It has been a tradition of our Institute, on visiting foreign countries, to confer the gold medal of the Institute on a distinguished metallurgist, should a distinguished metallurgist exist in that country. And I may mention that we conferred the gold medal of the Institute in past years upon Mr. Peter Cooper; upon Mr. A. L. Holley; upon the Hon. Abram S. Hewitt; upon Mr. John Fritz, who is now with us; upon your Professor Howe; and now again it has not been for want of finding a distinguished metallurgist in your great country—in fact, it has been rather an embarrassment to us to select amongst so many distinguished men one upon whom we should confer this honour. It is said that lookers on see the best of the game, and probably we British metallurgists, who have not been impeded, or thwarted, or jostled in the race to the goal, can view with a calmer judgment the merits of Mr. Carnegie, and the benefits which he has conferred upon the great iron and steel industry which we represent. If I were a Scotchman I might be conceited. But I am not a Scotchman, and therefore I do not venture to take away from the United States the honour of a great American by claiming him for my own, because I recognise that "the germ so pregnant with celestial fire" was reared in an American atmosphere, amongst American institutions, and, what is still more, it enjoyed American opportunities. You had here the great sources of power in nature stored up in prodigal abundance. It wanted the master mind to develop those resources, and to use them to the benefit and advantage of the human race. You had great scientific men, great chemists, and great mechanics. But the great mechanic does not develop the iron and steel mines of the world alone. The great chemist points out to you what you should do and what you should select. But the great chemist does not develop those resources until he has been associated with the energy and the knowledge of the great man of business. You have had in Mr. Carnegie the judgment to foresee the great developments of your country, the sagacity to obtain control of the great resources of coal and iron with which you are so prodigally endowed. But you had still more, the sagacity to choose and to use the instruments, and to give them the opportunities which their genius afforded to develop those great resources. I remember being with Mr. Carnegie in his Pittsburg works fourteen years ago, when some complicated machinery which had just been applied was being shown to us. I ventured rather timidly to ask Mr. Carnegie whether he understood the details of that machinery; and he said, "No," frankly, "I do not understand the details of much of my machinery, but what I do claim to understand is the human machine." And I think he has understood the human machine. He has gathered round him a magnificent staff, and he has encouraged that staff by generous remuneration, and by wide opportunities, to put forth the utmost of their powers to give the magnificent results which have astonished us, and have astonished the whole world. But it is not for this and for this alone that we Britishers desire to confer this honour upon Mr. Andrew Carnegie. He has acknowledged, in his address to you, how much he is indebted to the old world for inventions in iron and steel. He was very early searching with his keen insight and judgment for every improvement and every invention that was likely to develop the resources which he possessed. One of his earliest acquirements was the Dodds' patent for case-hardening rails; and I happen to know that he made a very generous arrangement with Mr. Dodds, and he has involvements which have followed that generous arrangement. There is in this room an old friend of mine, and of Mr. Carnegie, a gentleman who happened to be present when the agreement with Mr. Dodds was made. Mr. Carnegie said, "Now I will talk to my friend here, and you draw out an agreement." Mr. Dodds was a long time racking his brain and fumbling over his paper, until at last our friend grew impatient and said, "Now, Mr. Dodds, will you allow me to assist you;" and Mr. Dodds replied, "Well, if it had been an engineering specification or a specification of machinery I should have had no difficulty; but these legal agreements are a great difficulty to me." Mr. Carnegie sat down, and as you can easily understand, he drafted a short, concise, and effective agreement in a very few minutes. He then presented it to Mr. Dodds, and said, "Now, Mr. Dodds, here is the agreement, and if you find any serpents in it I shall be glad to take them out." Well, in all his agreements I am able to state he has never introduced any serpents to take away from the inventor the advantage of the agreement he has made. Following the Dodds' agreement, Mr. Carnegie made his arrangement with Sir Henry Bessemer; and I may say, amongst the benefits which Sir Henry has conferred on the human race, the largest share of these benefits have fallen upon the United States. I remember, at our last meeting here, the Hon. Abram S. Hewitt said the results of the Bessemer invention had enabled the United States to pay off the whole of its debt—and I believe he was not speaking extravagantly, because without the Bessemer invention you would not have been able to develop your railroads, or connect your vast territories together in this bond of union, unless you had been able to turn out with rapidity the products the great works of the United States have turned out, and the enormous mass of Bessemer rails which have covered the earth. Then the Siemens gas-furnace invention also was drawn from the old country. And following that, Mr. Carnegie made a very prompt and a very generous arrangement with Mr. Thomas, but for reasons of your own, from natural reasons, the Thomas process has not been used to the extent that it has been used in Germany, owing to the nature of their minerals. But, nevertheless, that agreement was made. For all this, and for all his generous appreciation of the mechanical arrangements, and the mechanical details which have been properly remunerated when they have been used—for all these things, and for the acknowledgments which you now, sir, have again generously given, we desire to acknowledge by conferring upon you the greatest honour which we can confer, and that is the Bessemer gold medal "for services to the iron and steel trade." In presenting it, I would wish to say, when the great works built up are changed and are directed by new men on newer methods, your name will ever be remembered in my native land as one who used his vast potentialities to promote literature and learning, and showed by his actions that he loved his fellow-man.

Mr. **Carnegie**, in reply, said: My dear friend, Sir James, I have listened to what you have said. It has fallen to my lot to receive many addresses, especially when receiving freedoms of cities when the Mayors very often have to say what their position demands rather than what they inwardly feel, and I have always said to myself, this is, of course, in the Pickwickian sense, "I know that the Mayor is doing his best, and I understand it perfectly, let him go on." But when Sir James Kitson speaks as he has spoken it becomes somewhat serious, because his position in the House of Commons is very high. One of the leaders of the party told me not long ago that he made the most weighty speech that has been made recently in the House of Commons, so that there is a man behind Sir James when he speaks, and he weighs his words very carefully, and therefore he is a very dangerous presenter of anything to another. You might turn my head, Sir James, when all the Mayors that ever spoke, who presented me with freedom of cities, would not affect that hard commonsense with which I flatter myself I am more or less endowed. I am very glad that you discriminated in your eulogy—what I told you was so true! I do not understand the details of steel manufacture, I have no claim to knowledge of the various processes which result in the successful making of steel. Therefore, when presented with a testimonial by the Stevens Institute I disclaimed, as I do now, any merit, and I said that I thought the fitting epitaph for me was: "Here lies a man who knew how to get round him men cleverer than himself." I might have some difficulty in proving this satisfactorily were it not that Mr. Corey and Mr. Gayley and some others before me were of the number. But there are others just like them. There are three classes of men in the world. There are men who go through this world doing great work, who do not receive the recognition which they deserve. There is another class of men of whom we can say, "Yes, they did work, and have been duly appreciated; yea, rated according to their services." There is a third class, who really do feel and know that they get ten times more recognition than they are entitled to. And I think, after receiving the Bessemer gold medal, you will have no difficulty in divining to what class the President of the Iron and Steel Institute belongs. Of course, the ladies, whom we are delighted to see here in such numbers, could never be placed in the third class, because it would be impossible to rate them higher than they deserve. Nor scarcely even in the second. But, Sir James, there is a serious point of view when a man receives such a tribute from his fellows. I do not deny that such are of great service to me. I do not hesitate to say that such tokens do me great good and tend to make me a better man. They do not exalt, but they humble one; because every one of these testimonials that I am surrounded by, tell me that my fellow-men did have an appreciation of me, did have kindly feeling for me, and did picture me in their imagination as one worthy of their esteem. I think he must be a poor character who, knowing that he is receiving higher honours from his fellows than he deserves, does not resolve that he will become in some degree akin to the ideal they have formed of him. Therefore, I welcome all these tributes as better than titles, better than rank, better than wealth; these are the patents of a true nobility which I shall hand down to those who come after me, with this message, that they humbled me when presented, but they proved my supporters and good angels all through my life. This gold medal I hope to hold and pass to my descendants as I received it from you, pure gold, untarnished in my keeping.

The meeting was followed by a reception and dance at the invitation of the New York Reception Committee.

On Wednesday, October 26th, the General Meeting was held at ten o'clock in the ball-room on the eighth floor of the Hotel Astor. About 350 members attended the reading of papers and discussions that took place in the morning and the afternoon. The President occupied the chair.

The SECRETARY read the minutes of the last meeting in London, which were confirmed and signed.

The PRESIDENT nominated as Scrutineers Mr. H. Bauerman (London) and Mr. James Proctor (Lilleshall); and on the completion of their scrutiny, they announced that the following sixty-four candidates had been elected members of the Institute:—

NAME.	ADDRESS.	PROPOSERS.
Andrews, Charles Reginald	Wortley Iron Works, near Sheffield	R. A. Hadfield, J. O. Arnold, Andrew McWilliam.
Atkins, Thomas Goodson	Reliance Steel Works, Attercliffe, Sheffield	G. E. Senior, B. W. Winder, Percy W. Lee.
Bain, Andrew . . .	Glen Tower, Hunter's Quay, Argyllshire	Archibald Colville, W. Clark, James G. Jenkins.
Bayliss, Horace William	The Lloyd House, Wolverhampton	Sir B. Hingley, Alexander McBean, Walter Jenks.
Booth, William . . .	Longfield, Rodley, Leeds	Arthur Booth, Arthur Horsfield, A. Tannett-Walker.
Bowden, Geo. R. Harland	Hucclecote Court, Gloucester	James Riley, William Evans, Isaac Butler.
Brooks, James C. . .	5th and Washington Avenues, Philadelphia, Pa., U.S.A.	W. H. Morris, C. M. Schwab, Wm. Sellers.
Burchard, Anson W. .	44 Broad Street, New York, U.S.A.	James Douglas, G. C. Henning, C. Kirchhoff.
Burrows, Lycurgus. .	Junction Road, Sheffield	J. E. Fletcher, Ambrose Firth, W. B. Hamilton.
Capp, John A. . . .	Schenectady, New York, U.S.A.	B. F. Fackenthal, jun., Henry D. Hibbard, G. G. McMurtry.

NAME.	ADDRESS.	PROPOSERS.
Capron, Athol John .	Messrs. Davy Bros., Ltd., Park Iron Works, Sheffield	John D. Ellis, Sydney J. Robinson, W. A. Hartly.
Carrington, George .	Dunston Villa, Sheepbridge, Chesterfield	Herbert Pilkington, M. Deacon, John H. Coghlan.
Cleghorn, Edward D. .	The Acme Lathe and Products Co., Ltd., Trafford Park, Manchester	Thomas Ashbury, D. Wood, William Spencer.
Cradock, Norman . .	Westfield House, Wakefield	Arthur Horsfield, Percy S. Cradock, F. H. Wigham.
Crompton, Thomas. .	Ashton, near Wigan .	John Wood, T. M. Percy, V. F. Abbott.
Davies, John P.. . .	1 Russell Street, Dowlais, Glam.	J. M. While, Arthur W. Richards, G. Bellwood.
Davies, John R.. . .	10 Heathfield, Swansea	John Paton, F. T. Thomas, Harold M. Thomas.
Diefenderfer, Victor James	437 Geopp Street, Bethlehem, Pa., U.S.A.	James Roberts, Harry Silvester, J. W. Hall.
Ekman, Gustaf . . .	Morgårdshammar, Sweden	Lars Uno Lindberg, J. A. Brinell, Axel Wahlberg.
Espinasse, Eugene . .	Saint Juéry (Tarn), France	P. Bayard, A. Pourcel, F. Osmond.
Fairholme, Frederick Charles, Assoc.M.Inst.C.E.	Bolton Hall, near Rotherham	R. A. Hadfield, J. Rossiter Hoyle, W. A. Hartley.
Fox, Gerard Elsey . .	1 Grange Road, Clifton, Bristol	Cyrus Braby, W. S. Squire, J. H. Barber.
Goldstein, Oskar . .	Monterey, Mexico . .	E. Schrödter, P. Eyermann, Andrew Carnegie.
Gunter, William Augustine	Marsh Side and New Yard Iron Works, Workington	T. E. G. Marley, Richard Williamson, Richard Sharp.
Haeberlin, Ferdinand	5 Whittington Avenue, Leadenhall Street, London, E.C.	Robert Russell, Henry Bumby, T. F. Craddock.
Hampton, John Arthur	32 Sandwell Road, Handsworth, Birmingham	James Roberts, Harry Silvester, J. W. Hall.
Hayne, William Crosier	80 Goswell Road, London, E.C.	Edward Wood, Joseph Gregory, Henry C. Simpson.
Head, William Howard	26 Lombard Street, London, E.C.	William Whitwell, Percy C. Gilchrist, J. E. Stead.
Holcomb, James Rogers	Midvale Steel Company, Philadelphia, Pa., U.S.A.	Henry D. Booth, Axel E. Petre, Charles J. Harrah.
Hulst, Nelson Powell .	Wolvin Building, Duluth, Minnesota, U.S.A.	James Douglas, James Gayley, W. B. Devereux.
Huxley, Samuel. . .	Osborne House, Pontnewynydd, Pontypool, Mon.	Aubrey I. R. Butler, Austin J. Ledwith, J. C. W. Humfrey.
King, Thomas Cobb .	66 Greencroft Gardens, London, N.W.	Greville Jones, Walter L. Johnson, E. D. Morgan.

Name.	Address.	Proposers.
Knowles, Richard	Glen Villa, Basford Park, Stoke-on-Trent	W. H. Davies, John Petherick, S. S. Horsfield.
Knox, Samuel Lippincott Griswold	South Milwaukee, Wisconsin, U.S.A.	Thos. M. Drown, Albert Ladd Colby, William W. Coleman.
Lewis, David	Dowlais Iron Works, Dowlais, Glam.	William Evans, John Evans, David Jenkins.
Lewy, Wilhelm	Hoza, 47 Warsaw, Poland	G. G. Coppel, Sydney J. Robinson, J. Stanley Watson.
Luther, William Henri	Eclipse Works, Petersfield Road, Glasgow	Frederick Braby, James Bennie, David Sturrock.
Lysaght, Daniel Connor	Portshearth House, near Chepstow, Mon.	J. E. Stead, W. R. Lysaght, S. Whitmore.
Macfarlane, James	Annieslea, Motherwell	James Kerr, D. Colville, Andrew Lamberton.
Maré, Baltzar Emil Leo de	Midvale Steel Company, Philadelphia, Pa., U.S.A.	Henry D. Booth, Axel E. Petre, W. E. Firth.
Marsh, Harry Parker	Ponds Steel Works, Sheffield	R. A. Hadfield, Lewis J. Firth, J. Rossiter Hoyle.
Massey, Harold Fletcher	Messrs. B. & S. Massey, Openshaw, Manchester	G. R. Dunell, Ernest F. Lange, Thomas Barningham.
Mechan, Samuel	Scotstoun Iron Works, Glasgow	John F. Miller, William Jacks, W. Howat.
Mitcheson, George Arthur, F.G.S.	Longton, Staffordshire	H. J. Warrington, Henry Bumby, Thomas Turner.
Olsson, William	Centralpalats, Stockholm	Henry Louis, E. P. Martin, Geo. Ainsworth.
Page, Davidge	Clun House, Surrey Street. Strand, London, W.C.	J. F. L. Crosland, Enoch James, W. F. Pettigrew.
Pomeroy, Lewis Roberts	44 Broad Street, New York, U.S.A.	S. T. Wellman, G. C. Henning, C. Kirchhoff.
Rice, Edwin Wilbur, jun., M.Inst.C.E.	Schenectady, New York, U.S.A.	Andrew Carnegie, J. Fritz, C. Kirchhoff.
Russell, James	Messrs. Stewarts & Lloyds, Ltd., British Tube Works, Coatbridge, N.B.	P. N. Cunningham, James Kerr, C. F. MacLaren.
Schobinger, Joseph Anton	Villa Musegg, Lucerne	Lieut.-Col. J. H. Cowan, William Whitwell, Sir E. H. Carbutt.
Simonds, Daniel	Fitchburg, Mass., U.S.A.	R. A. Hadfield, Sydney J. Robinson, Henry S. Downe.
Smith, Harry J.	The Acme Lathe and Products Co., Ltd., Trafford Park, Manchester	Thomas Ashbury, D. Wood, William Spencer.
Sneddon, Richard	Netherton House, Wishaw, N.B.	A. Colville, D. M. Maclay, T. B. Mackenzie.
Spaeter, Carl, jun.	Coblentz, Germany	E. P. Martin, Otto Eichhoff, G. E. Woof.

Name.	Address.	Proposers.
Spånberg, John	Norrahammar, Sweden	Axel Wahlberg, Tom Bergendal, Lars Yngström.
Spranger, Robert William	81 Via Cavour, Florence, Italy	Isaac Butler, E. P. Martin, Alfred Baldwin.
Stein, John Gilchrist	Bonnybridge, Stirlingshire	John Tennent, F. Finlayson, J. S. Trinham.
Stewart, Sir David, M.A., LL.D.	Banchory House, Aberdeen	James G. Jenkins, Peter Donaldson, W. Clark.
Sumner, Edward H.	324 Romford Road, Forest Gate, London, E.	F. W. Harbord, Perry F. Nursey, Samuel Rideal.
Swanne, James	Bromford Mills, Erdington, near Birmingham	Harry B. Toy, W. H. Hatton, William Darby.
Taylor, Henry Francis	Middleton House, Briton Ferry, Glam.	G. H. Davey, Robert Roberts, H. Davies.
Wanklyn, William Lumb.	St. Arvan's, Chepstow, Mon.	John Paton, W. R. Lysaght, M. Deacon.
Williamson, Robert Summerside, M. Inst. C.E.	Cannock Wood House, Hednesford, Staffs.	Hon. E. F. Leveson-Gower, F. W. Llewelyn, W. H. Davies.
Wood, William Wilkinson, jun.	Wardsend Steel Works, Sheffield	F. C. Wild, W. J. Bedford, B. G. Wood.

THE PRESIDENT ELECT.

The **President** said: I was fortunate in having such an illustrious predecessor, and I am equally fortunate in my illustrious successor. The next President will be Mr. R. A. Hadfield, of Sheffield. I have only to mention his name to show you that no better person could have been honoured. I beg also to state that we are in receipt of an invitation from the coming President, which I will now read. It is addressed from Sheffield, and dated 12th October 1904, and is as follows:—

"It is with much regret that I find several very pressing business matters here will prevent my being able to accompany the Iron and Steel Institute on their approaching trip. From personal experience last year, and on many previous occasions, I know how warm will be the welcome of the metallurgists of America to their British confrères, and I wish I could have been present to share in it, especially, too, as from what I saw of the Exposition when visiting St. Louis last year, this must be of great interest and educational value. It is, I believe, usual to make some reference at the autumn meeting to the name of the probable incoming President for the next term. If this is done, may I ask that you will at the same time express my great regret to all American friends that I am unable to come over again so soon after my trip last season.

"I may say that I have seen our local member of the Council, Mr. J. D. Ellis, of Messrs. John Brown & Co., of this city, who has always shown so much interest in our Institute, and he agrees with me that, at any rate as regards his firm and my own (and I think, therefore, there is no doubt about others agreeing), we should be glad to give a most hearty welcome to the Iron and Steel Institute should it be decided that they visit Sheffield next year, and I hope that you, who have done so much for the advancement of metallurgy in the world, will then be amongst our visitors."

RETIRING MEMBERS OF COUNCIL.

The SECRETARY, in accordance with Rule 10, submitted the following list of the Vice-Presidents who would retire by rotation in May 1905: Mr. A. Keen, Sir W. T. Lewis, Bart., and Mr. P. C. Gilchrist. The following five members of Council would also retire: Mr. A. T. Tannett-Walker, Mr. F. W. Webb, Mr. J. E. Stead, Sir A. Hickman, Bart., M.P., and Sir E. H. Carbutt, Bart.

The first paper read and discussed was that by Mr. James Gayley on the "Application of Dry-Air Blast to the Manufacture of Iron," which is printed on p. 274. On the motion of the President, a cordial vote of thanks was passed to Mr. Gayley for his epoch-making paper.

The following paper was then read:—

THE INFLUENCE OF CARBON, PHOSPHORUS, MANGANESE AND SULPHUR ON THE TENSILE STRENGTH OF OPEN-HEARTH STEEL.

BY H. H. CAMPBELL, STEELTON, PA.

MANY attempts have been made to write a formula by which to calculate the strength of steel from its chemical composition, but most of these endeavours have failed because there were too many disturbing conditions. It is idle to collect from the pages of trade papers, books, or the proceedings of scientific societies, a multitude of observations. The combination of such results will simply show that steel of the same composition will vary in tensile strength through wide limits—a fact that has been known for generations. That cold working, overheating, and many another form of heat treatment alter fundamentally the strength of steel, is ancient history, although it is only recently that the microscope has pointed out the road to an explanation of the phenomena.

It may be urged that the microscopic structure must be taken into consideration in any formula giving the ultimate strength, but from the standpoint of the present investigation this is unnecessary. We are trying to determine primarily, not what changes in ultimate strength may be made by variations in the condition of carbon, but what effect is produced by changes in the amount of carbon, when its condition remains constant. For such an inquiry, in order that the condition of the carbon should remain as nearly uniform as possible, it is essential that all test-pieces be made under the same conditions; and it is believed that the tests described in this paper satisfy that requirement. The investigations were made at the works of the Pennsylvania Steel Company, Steelton, Pa.; the ingots from which the tests were made were 6 inches square in every case; they were heated in the same furnace and forged at the same hammer into billets of the same size; these billets were reheated in the same furnace by the same men and rolled in the same set of rolls into 2- by ⅜-inch bars of about the same length.

These were cooled under the same conditions, broken in the same machine by the same men, and analysed in the same laboratory by the same staff.

First Investigation.

About ten years ago extensive calculations were made on such bars at Steelton by the method of least squares.* In this case the bars of similar composition were grouped together, and the carbon of the group was determined by combustion upon a sample containing an equal amount of drillings from each bar. Such a grouping of the tests would give rise to error if unlike bars were put together; so that this was avoided as far as possible. A greater cause of trouble lies in the fact that, in the method of least squares, any error in one factor affects the other factors. If for any reason the value of phosphorus comes out higher than the real truth, the value of carbon may suffer accordingly. Still greater is the objection that no factor can be used in the work unless it really has a decided influence on the results. This was illustrated when sulphur and copper were used as factors, the values found for them being absurd.

In acid steels, it appeared that carbon and phosphorus were the important elements to be considered; and it was assumed that the strength of steel was made up of the effect of a certain content of iron, plus the effect of a certain content of carbon, plus the effect of a certain content of phosphorus. Thus in a metal containing 0·20 per cent. of carbon and 0·08 per cent. of phosphorus, and having a tensile strength of 70,000 lbs. per sq. inch, we may write the following equation (the iron being determined by difference):

$20\,C + 8\,P + 9{,}972\,Fe = 70{,}000$; C, P and Fe being constants, representing the effect upon the tensile strength in pounds per square inch of 0·01 per cent. of carbon, phosphorus and iron respectively. In this way each group of tests furnished a formula and the combination of these by the method of least squares gave the following results:

For Acid Steel: ($C = 1210$; $P = 890$; $Fe = 38{,}600$.)

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* Full details of the work will be found in *The Manufacture and Properties of Iron and Steel*, pp. 482–528. New York Engineering and Mining Journal Company, 1904.

38,600 Iron + 1210 Carbon + 890 Phosphorus + R = Ultimate Strength.

For Basic Steel: (C = 950; P = 1050; Fe = 37,430, and Mn = 85.)

37,430 + 950 Carbon + 1050 Phosphorus + 85 Manganese + R = Ultimate Strength.

The iron, carbon, phosphorus, and manganese are expressed in units of 0·01 per cent., and R, as well as the ultimate strength, in pounds per square inch. R is a variable to allow for heat treament. In angles and plates, about ⅜-inch or ½-inch in thickness, and finished at a fairly high temperature, R is zero.

In this formula, Fe, 38,600, represents the value independently determined for pure iron. From a mathematical standpoint there can be no objection to including iron as one of the factors in the problem, but practically there are the following reasons to the contrary:—

1. There is a doubt whether the real basis of strength varies with each increase or decrease in the total metallic iron. It may be that the datum-plane is the same, whether the steel contains 99·6 per cent. or 99·1 per cent. of iron.

2. Since the iron is determined by difference, all the errors in determining carbon, manganese, and phosphorus, as well as the total contents of sulphur, copper, silicon, and other elements, may make a composite error of no small moment; and this is all embodied in the figure representing iron.

3. The range of variation in the percentage of iron is not sufficiently great to give a good working basis.

Notwithstanding all these objections to the methods of determination, the derived formulæ given above have been of the utmost practical importance. They have been applied to every heat of steel made by the Pennsylvania Steel Company for the last ten years; and there has rarely been, in the ultimate strength of soft steels, a difference of more than 2500 lbs. per square inch between the result given by the formula and the record of the testing machine. In most cases the error has been much less than 1500 lbs.; and so great is our confidence in the formulæ, that chemical determinations are always repeated when they are not confirmed by the machine test. In view of such an experience in everyday commercial work, it would be rash to say that the method is entirely wrong, or that the formulæ do not represent actual conditions.

Second Investigation.

To check the first investigation, two entirely new series of bars were collected: one of nearly seven hundred from acid heats, and the other of eleven hundred from basic heats. Duplicate determinations were made on each bar for phosphorus and manganese. The carbon was determined in three ways:—(1) the bar was analysed by combustion (duplicate tests being made in case of doubt); (2) the bar was analysed by the colour test; (3) a piece of the ingot from which the bar had been made was cut off at the hammer, and analysed by the colour test.

Three bars were pulled on each heat, two on one testing machine and one on another. The figure used is the average of the results obtained on the two machines, not the average of the three bars.

In order to plot the data, all heats were combined which showed carbon from 0·075 to 0·125 per cent.; from 0·125 to 0·175 per cent., and so on—making a division for each additional 0·05 per cent. of carbon. Table I. gives the list of groups thus formed.

The division of the groups according to the way in which the carbon was determined is important, because many heats may change their grouping according to the way the carbon is determined; thus if a heat showed 0·12 per cent. of carbon by combustion, it would appear in Fig. 1 in line AA, at the point representing the range between 0·075 and 0·125 per cent. of carbon; while, if the colour determination showed 0·14 per cent., it would appear in the line BB at the point representing the range between 0·125 and 0·175 per cent. In this way the three sets of lines may be viewed as the result of three independent investigations.

The lines AA, BB, and CC in Fig. 1 are not plotted directly from Table I., but the data have been combined by recognised scientific methods to allow for the unequal number of heats in

TABLE I.—*List of Groups used in Determining the Effect of Carbon, Phosphorus, and Manganese.*

Division.	Number of Heats.	Average Chemical Composition.			Ultimate Strength.
		Carbon.	Phosphorus.	Manganese.	
		Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. In.
A, acid test bars; carbon by combustion.	50	0·1118	0·0545	0·408	58,012
	131	0·1463	0·0567	0·437	61,039
	58	0·1995	0·0579	0·475	66,809
	22	0·2463	0·0563	0·484	70,736
	50	0·3065	0·0476	0·528	79,058
	120	0·3501	0·0466	0·537	83,093
	103	0·4000	0·0400	0·518	87,156
	86	0·4491	0·0376	0·520	92,824
	42	0·4961	0·0363	0·519	98,224
	8	0·5460	0·0354	0·495	102,346
	6	0·5863	0·0330	0·493	107,398
B, acid test-bars; carbon by colour.	45	0·113	0·0545	...	58,535
	164	0·145	0·0568	...	62,407
	47	0·197	0·0560	...	67,052
	8	0·249	0·0527	...	72,728
	36	0·304	0·0494	...	80,776
	53	0·352	0·0380	...	86,369
	45	0·395	0·0358	...	92,759
	18	0·444	0·0330	...	98,576
	2	0·480	0·0360	...	103,120
C, acid test-ingots; carbon by colour.	34	0·118	...	...	57,599
	160	0·145	...	...	61,189
	61	0·190	...	...	67,482
	17	0·250	...	...	74,239
	84	0·307	...	...	80,491
	160	0·346	...	...	85,073
	98	0·397	...	...	91,434
	59	0·446	...	...	97,439
	15	0·507	...	...	105,656
D, basic test-bars; carbon by combustion.	135	0·0451	0·0082	0·243	46,703
	125	0·0974	0·0084	0·422	50,013
	134	0·1521	0·0116	0·436	55,650
	246	0·2044	0·0113	0·472	61,236
	263	0·2484	0·0110	0·474	64,744
	125	0·2935	0·0106	0·464	68,307
	27	0·3413	0·0113	0·461	72,065
	11	0·3932	0·0120	0·499	78,625
	1	0·4310	0·0070	0·390	83,305
E, basic test-bars; carbon by colour.	173	0·047	0·0076	...	47,084
	96	0·093	0·0100	...	51,228
	189	0·154	0·0122	...	58,202
	322	0·200	0·0118	...	63,184
	235	0·248	0·0116	...	65,813
	51	0·288	0·0125	...	70,786
	3	0·343	0·0087	...	79,252
F, basic test-ingots; carbon by colour.	131	0·057	...	...	46,431
	131	0·093	...	...	49,917
	152	0·150	...	...	56,264
	365	0·203	...	...	62,241
	210	0·246	...	...	66,401
	72	0·295	...	...	71,011
	10	0·350	...	...	80,013
	2	0·400	...	...	80,272

the groups. Thus by combining groups 1, 2, and 3, we get the first point of AA; from groups 2, 3, and 4 we get the second point; and so on. The result of this combination gives Table II.

Table II.—*Combination of Data in Table I. by Groups of Three to obtain Construction Points for the Lines in Fig.* 1.

Class.	Chemical Composition.			Ultimate Strength.
	Carbon.	Phosphorus.	Manganese.	
	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. In.
A, acid test-bars; carbon by combustion; line AA.	0·1520	0·0565	0·440	61,806
	0·1713	0·0570	0·453	63,637
	0·2486	0·0537	0·497	72,185
	0·3268	0·0480	0·529	80,626
	0·3609	0·0443	0·528	83,886
	0·3943	0·0419	0·526	87,155
	0·4357	0·0384	0·519	91,278
	0·4693	0·0371	0·518	95,052
	0·5130	0·0358	0·513	99,795
B, acid test-bars; carbon by colour; line BB.	0·1489	0·0562	0·443	63,072
	0·1600	0·0564	0·453	64,379
	0·2437	0·0541	0·491	72,980
	0·3255	0·0434	0·519	83,168
	0·3534	0·0403	0·515	87,012
	0·3827	0·0364	0·513	90,742
	0·4112	0·0351	0·506	94,689
C, acid test-ingots; carbon by colour; line CC.	0·152	...	...	62,216
	0·164	...	...	63,734
	0·257	...	...	74,937
	0·327	...	...	82,893
	0·351	...	...	85,771
	0·381	...	...	89,341
	0·423	...	...	94,734
D, basic test-bars; carbon by combustion; line DD.	0·0978	0·0094	0·366	50,834
	0·1639	0·0107	0·450	57,001
	0·2115	0·0113	0·465	61,502
	0·2403	0·0110	0·471	64,086
	0·2681	0·0109	0·470	66,297
	0·3081	0·0108	0·466	69,626
	0·3582	0·0113	0·469	74,203
E, basic test-bars; carbon by colour; line EE.	0·1010	0·0101	0·384	52,540
	0·1688	0·0116	0·458	59,739
	0·2036	0·0118	0·466	62,750
	0·2260	0·0118	0·468	64,839
	0·2564	0·0117	0·469	66,830
F, basic test-ingots; carbon by colour; line FF.	0·102	...	...	51,150
	0·168	...	...	58,339
	0·204	...	...	62,195
	0·227	...	...	64,575
	0·262	...	...	68,010
	0·304	...	...	72,303

The lines AA, BB, &c., plotted therefrom, are more nearly representative of the true conditions, and are straighter than lines would be if plotted directly from Table I.

In Fig. 1 are shown all six lines. The line BB, founded on the colour-determination of carbon in the acid test-bar, agrees very closely with CC, founded on colour carbons from the acid test ingot. In the same way, but less closely, the line EE, representing colour carbons on the basic bar, agrees with the line

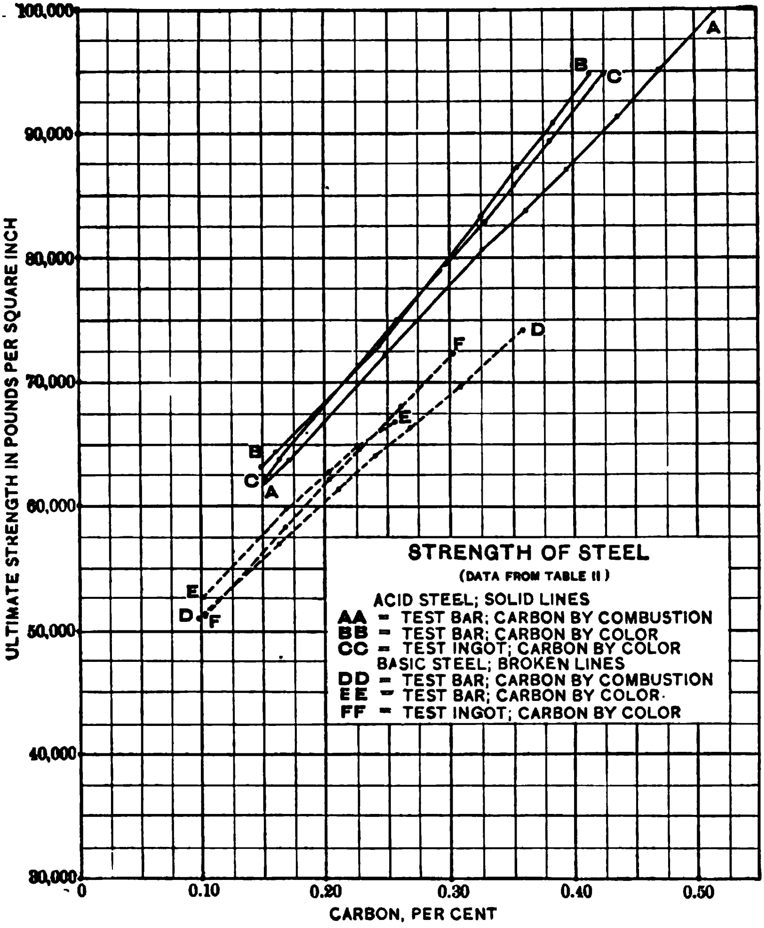

FIG. 1.—Strength of Steel.

FF, representing colour carbons on the basic ingot. This additional investigation of the test ingot was undertaken simply as a check to the other results; and, since it agrees as nearly as could be expected with the colour records on the bar, no further mention will be made of its results, comparison being made only between the combustion and the colour-work on the test bar. It may be well, however, to note that the line FF does not dip down at the upper end like EE, and this fact, taken in conjunction with the straightness of all the other lines, indicates that this dip in EE must be caused by errors in determination.

In the acid steels there is quite a difference between AA and BB, and in the basic steels between DD and EE. For a given amount of carbon, the results on the bar when analysed by the colour method show a higher tensile strength than when carbon is determined by combustion, because a certain amount of temper carbon is found by combustion which has little effect upon the ultimate strength. Determinations by colour are often unsatisfactory; but when all the work is done in one laboratory, the results may be looked upon as comparable, and the reasonable straightness of the lines, as plotted, is good evidence that the chemical work was reliable.

The lines AA, BB, &c., take no account of variation in the content of phosphorus or of manganese. It is well known that phosphorus in small proportions adds to the tensile strength; in the first investigation by the method of least squares it was found that 0·01 per cent. raised the strength of acid steel 890 lbs., and basic steel, 1050 lbs. per square inch; and experience has indicated that these values are very near the truth. In the present investigation the value of carbon is first determined, and then that of manganese and phosphorus, but in order to find the value of carbon accurately it is essential to know the influence of both manganese and phosphorus. This makes necessary the method of successive approximations, the values found in the first approximation being used in the second, and so on until the changes made in values are unimportant. In the present case the methods used avoid to some extent the dependence of one determination upon another. Thus in the line AA, carbon is the one great variable; the proportions of phosphorus and manganese are not constant, but the groups of high-carbon steel contain about the same amount of manganese and phosphorus as the groups of low-carbon steel, and hence the line will give a provisional value of carbon. The general trend is determined by stretching a thread along its length and noting the tangent made with the horizontal. In this way the line AA indicates a value for carbon of about 1050 lbs. for each 0·01 per cent.; allowances have yet to be made for the effect of phosphorus and manganese, but this figure serves as a working basis for similar provisional estimations of the other elements.

In explaining the method used to determine the value of phosphorus and manganese, no mention will be made of these provisional values, the figures given being in each case the final results.

THE EFFECT OF PHOSPHORUS ON ACID STEEL.

The investigation into the effect of phosphorus will be confined to acid steel, for in the basic steels under consideration the proportions of phosphorus were so low that the differences were almost within the limits of chemical error. Two methods have been used, one serving as a check upon the other.

First Method.—Referring to Table I. under the head of acid steels, carbon determined by combustion, the first group is composed of 50 heats averaging 0·1118 per cent. of carbon, 0·0545 per cent. of phosphorus, 0·408 per cent. of manganese, and 58,012 lbs. per square inch in ultimate strength. These 50 heats were separated into two groups, of high- and low-phosphorus respectively. The terms "high" and "low" are relative, and signify that the heats were arranged in a column according to their phosphorus content, the upper half of the list being called "high" and the lower half "low." The result of this process applied to each group gave in each case two equal divisions showing a certain difference in carbon, in manganese, in phosphorus, and in ultimate strength. If the carbon and manganese had been uniform, the effect of phosphorus could have been found by simple division; but since they both varied, it was necessary to make allowance for them. If the difference in carbon were of any great amount a considerable error might be introduced; but as each group before division included only such heats as were within a range of 0·05 per cent. of carbon, the difference in this element in the high-phosphorus and low-phosphorus heats is in each case in the third decimal place.

Table III. shows the first method of finding the value of phosphorus from the acid steel bars in Table I. In each group we find the difference in ultimate strength, then allow for the variation in carbon and in manganese, and find the difference in ultimate strength due to phosphorus alone; then divide by the variation in phosphorus and obtain the effect of one unit of phosphorus in the one group under consideration. If all the groups were composed of the same number of heats, it would suffice to take an average of these values of phosphorus; but as each group is made up of a different number, it is necessary to make a true average by multiplying the value found for each group by the number of heats in the group, and divide the sum of these results by the total number of heats. In this way the first method gives a value for phosphorus in acid steel of 807 lbs. for 0·01 per cent.

Second Method.—The bars were classified as before according to carbon, and then each of these main groups was subdivided according to phosphorus. Heats containing 0·03 per cent. of phosphorus constituted one group; those with 0·031 per cent. another; those with 0·032 per cent. another, and so on. Having made a list of these groups they were put together so as to give four or five points with about an equal number of heats in each, the result being shown in Table IV. In the last column is given what may be called the base, or the strength of the iron and phosphorus after allowing for carbon and manganese; this last column is plotted in Fig. 2. By combining the groups so as to rectify the lines by the method used in Table II., it will be found that in the line representing heats ranging between 0·075 and 0·224 per cent. of carbon, the phosphorus has a value of about 860 lbs. for each 0·01 per cent.; in the range from 0·225 to 0·374 per cent. of carbon, the value is 940 lbs.; between 0·375 and 0·524 per cent. of carbon it is 1290 lbs. This would indicate that as the percentage of carbon increases, the effect of each unit of phosphorus increases, but the difference is so unimportant and the margin of certainty so narrow that it will be better to make a true average of the three values. There were 239 heats giving a value of 860 lbs., 192 heats

TABLE III.—*Division of Heats to Determine the Effect of Phosphorus upon Acid Steel.*

NOTE.—In the sixth column an allowance is made of 1000 lbs. for 0·01 per cent. of carbon, and for manganese according to the sliding scale in Table VII.

Relative Phosphorus.	Chemical Composition.			Ultimate Strength.			Number of Heats in Group.	Product of Last Two Columns.
	Carbon.	Phosphorus.	Manganese.	Actual Records.	Difference Due to Phosphorus Alone.	Effect of 0·01 Per Cent. of Phosphorus.		
	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.		
High . .	0·1121	0·0635	0·405	58,543	...	...	...	...
Low . .	0·1114	0·0456	0·411	57,481	...	...	...	...
Diff. . .	**0·0007**	**0·0179**	**0·006**	**1,062**	**1045**	**584**	**50**	**29,200**
High . .	0·1470	0·0652	0·444	62,088	...	...	...	...
Low . .	0·1457	0·0483	0·432	60,006	...	...	...	...
Diff. . .	**0·0013**	**0·0169**	**0·012**	**2,082**	**1808**	**1070**	**131**	**140,170**
High . .	0·1963	0·0667	0·481	67,443	...	...	...	...
Low . .	0·2026	0·0490	0.470	66,174	...	...	...	...
Diff. . .	**0·0063**	**0·0177**	**0·011**	**1,269**	**1723**	**973**	**58**	**56,434**
High . .	0·2459	0·0658	0·489	71,292	...	...	...	...
Low . .	0·2467	0·0484	0·481	70,275	...	...	...	...
Diff. . .	**0·0008**	**0·0174**	**0·008**	**1,017**	**937**	**539**	**22**	**11,858**
High . .	0·3065	0·0564	0·546	80,111	...	...	...	...
Low . .	0·3065	0·0399	0·509	78,005	...	...	...	...
Diff. . .	...	**0·0165**	**0·037**	**2,106**	**1218**	**738**	**50**	**36,900**
High . .	0·3466	0·0545	0·540	83,669	...	...	...	...
Low . .	0·3543	0·0372	0·534	82,410	...	...	...	...
Diff. . .	**0·0077**	**0·0173**	**0·006**	**1,259**	**1861**	**1076**	**120**	**129,120**
High . .	0·3969	0·0470	0·520	87,104	...	...	...	...
Low . .	0·4031	0·0328	0·516	87,209	...	...	...	...
Diff . .	**0·0062**	**0·0142**	**0·004**	**−105**	**387**	**273**	**103**	**28,119**
High . .	0·4511	0·0441	0·524	93,673	...	...	...	...
Low . .	0·4473	0·0311	0·517	91,975	...	...	...	...
Diff. . .	**0·0038**	**0·0130**	**0·007**	**1,698**	**1066**	**820**	**86**	**70,520**
High . .	0·4949	0·0407	0·521	98,318	...	...	...	...
Low . .	0·4970	0·0327	0·517	98,145	...	...	...	...
Diff. . .	**0·0021**	**0·0080**	**0·004**	**173**	**226**	**282**	**42**	**11,844**
High . .	0·5430	0·0433	0·508	104,047	...	...	...	...
Low . .	0·5508	0·0275	0·483	100,645	...	...	...	...
Diff. . .	**0·0078**	**0·0158**	**0·025**	**3,402**	**3082**	**1951**	**8**	**15,608**
High . .	0·5815	0·0415	0·500	109,367	...	...	...	...
Low . .	0·5898	0·0288	0·490	106,412	...	...	...	...
Diff. . .	**0·0083**	**0·0127**	**0·010**	**2,955**	**3321**	**2615**	**6**	**15,690**
			Total				676	545,463
			Average					807

giving 940 lbs., and 231 heats giving 1290 lbs., so that the true average is 1033 lbs. For the sake of simplicity the value of 0·01 per cent. of phosphorus will be taken as 1000 lbs.

In reducing to a zero base, as in the last column of Table IV., there will be certain errors, since the values of carbon and manganese are not inerrant; but the original classification into groups of about the same carbon minimises the disturbing effect. Thus in Table IV. the first main division has five units; the highest carbon is 0·1540 per cent., and the lowest 0·1491 per cent., a variation of 0·0049 per cent. Carbon has been valued at 1000 lbs. for 0·01 per cent., and if perchance that value is in error by 50 lbs., the results determined from that division of the table will be wrong by only 50 × 0·49 = 25 lbs. The last column shows a strength of 47·328 lbs. for one base and 44·616 lbs. for the other, a difference of 2712 lbs., so that the

TABLE IV.—*Classification of Acid Heats according to Content of Phosphorus.*

NOTE.—In the last column a value of 1000 lbs. is given to 0·01 per cent. of carbon; the figure for manganese is taken from Table VII. Fig. 3 is plotted from the last column, but the data are combined to rectify the lines.

Limits of Carbon.	Number of Heats.	Chemical Composition.				Ultimate Strength.	
		Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Record.	After Deducting for Carbon and Manganese.
Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
0·075 to 0·224	39	0·1491	0·0396	0·439	0·0539	59,994	44,616
	54	0·1524	0·0500	0·430	0·0559	61,038	45,438
	38	0·1504	0·0557	0·441	0·0568	61,595	46,063
	61	0·1528	0·0617	0·445	0·0588	62,633	46,813
	47	0·1540	0·0717	0·447	0·0623	63,292	47,328
0·225 to 0·374	46	0·3373	0·0331	0·514	0·0477	79,636	42,805
	53	0·3317	0·0438	0·537	0·0529	81,231	44,444
	44	0·3265	0·0523	0·527	0·0538	81,197	45,194
	49	0·3120	0·0626	0·537	0·0537	80,390	45,792
0·375 to 0·524	52	0·4413	0·0271	0·514	0·0437	90,413	42,270
	63	0·4424	0·0343	0·508	0·0461	91,180	43,138
	54	0·4366	0·0404	0·521	0·0494	92,215	44,320
	62	0·4235	0·0504	0·534	0·0526	91,370	44,517

assumed error of 50 lbs. in the value of carbon produces an error of only 1 per cent. in the value of phosphorus in this particular division. This argument applies also to the determination of the other elements in both acid and basic steel.

Another important consideration applying equally to the work on phosphorus and on manganese is the concordance of results obtained from different divisions. A general average obtained by grouping any data into two primal divisions gives conclusions of very limited value, but in this paper the practice is followed of subdividing in order to compare results. Thus from three independent lines of Fig. 2 the values of phosphorus varied from 860 to 1290. It is quite possible that these

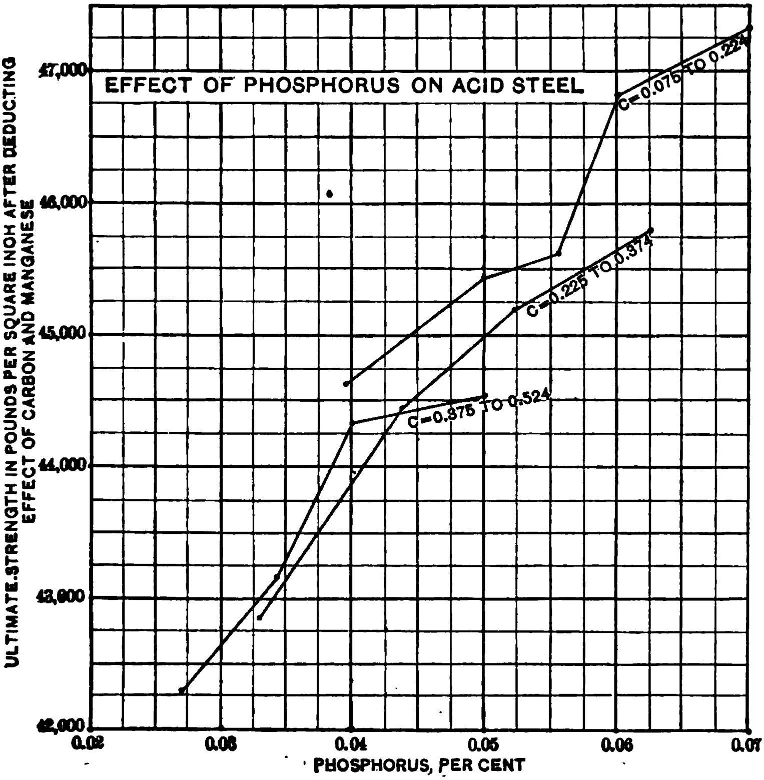

Fig. 2.—Effect of Phosphorus on Acid Steel.

variations were not accidental, and that the variation represents a law of increasing effect with higher carbons, but leaving all this aside it is certain that three separate determinations roughly agreeing with one another establish with reasonable certainty the general fact that 0·01 per cent. of phosphorus has a strengthening effect of somewhere about 1000 lbs. The validity of the conclusions is immeasurably superior to one based on a general average.

EFFECT OF MANGANESE ON ACID STEEL.

First Method.—The heats were divided into "low" and "high" manganese in the same way and within the same carbon-limits as already described in the determination of phosphorus. The results as given in Table V. show that the effect of one unit of manganese is greater as the carbon increases. The increase is not regular, but this is partly explained by the small number of heats in some of the groups. Combining the data so as to have three larger groups, and plotting the results, it was found that for each increase of 0·01 per cent. of carbon, the effect of 0·01 per cent. of manganese was 10 lbs. more. That is to say, if 0·01 per cent. of manganese strengthens a steel of 0·2 per cent. carbon by 160 lbs., it will strengthen a steel of 0·21 per cent. of carbon by 170 lbs. In the second method of determining manganese it is found that the increment is 8 lbs., which agrees fairly well with this valuation.

Second Method.—The heats were divided according to their content of manganese in the same way as explained in the second determination of phosphorus. The results as given in Table VI. and in Fig. 3 show that when the manganese is above 0·4 per cent. each increase in that element raises the strength, while with contents below 0·4 per cent. the tensile strength increases as the manganese decreases. The number of observations of low-manganese acid steels is not sufficient to prove this conclusively, but on another page it will be shown that in basic steel also a decrease in the manganese content below a certain point is not accompanied by a decrease in strength. It is probable that low-manganese implies the presence of oxide of iron, and that this strengthens the steel much more than it is weakened by the decrease in manganese.

The lines in Fig. 3 show that each increase in manganese above 0·4 per cent. is accompanied by an increase in strength,

TABLE V.—*Division of Heats to Determine the Effect of Manganese upon Acid Steel.*

NOTE.—In the eighth column a value is given both to carbon and phosphorus of 1000 lbs. for 0·01 per cent.

Limits of Carbon.	Relative Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.		
			Carbon.	Phosphorus.	Manganese.	Actual Records.	Difference due to Manganese Alone.	Effect of 0·01 Per Cent. of Manganese.
Per Cent.			Per Cent.	Per Cent.	Per Cent.	Lbs. Per Sq. In.	Lbs. Per Sq. Inch.	Lbs. Per Sq. Inch.
0·075 to 0·124	High	27	0·1156	0·0564	0·440	58,847	...	...
	Low	23	0·1073	0·0524	0·370	57,031	...	...
	Diff.		**0·0083**	**0·0040**	**0·070**	**1,816**	**586**	**84**
0·125 to 0·174	High	63	0·1517	0·0572	0·476	62,008	...	...
	Low	68	0·1413	0·0562	0·402	60,142	...	...
	Diff.		**0·0104**	**0·0010**	**0·074**	**1,866**	**726**	**98**
0·175 to 0·224	High	27	0·1974	0·0590	0·514	66,936	...	...
	Low	31	0·2012	0·0567	0·440	66,698	...	...
	Diff.		**0·0038**	**0·0023**	**0·074**	**238**	**388**	**52**
0·225 to 0·274	High	10	0·2413	0·0551	0·519	70,602	...	...
	Low	12	0·2505	0·0574	0·456	70,850	...	...
	Diff.		**0·0092**	**0·0023**	**0·063**	**−248**	**902**	**143**
0·275 to 0·324	High	26	0·3048	0·0524	0·568	79,926	...	...
	Low	24	0·3083	0·0425	0·486	78,118	...	...
	Diff.		**0·0035**	**0·0099**	**0·082**	**1,808**	**1168**	**142**
0·325 to 0·374	High	59	0·3513	0·0476	0·582	84,670	...	...
	Low	61	0·3489	0·0458	0·493	81,569	...	...
	Diff.		**0·0024**	**0·0018**	**0·089**	**3,101**	**2661**	**299**
0·375 to 0·424	High	53	0·3987	0·0405	0·556	88,554	...	...
	Low	50	0·4014	0·0394	0·478	85,675	...	...
	Diff.		**0·0027**	**0·0011**	**0·078**	**2,879**	**3039**	**390**
0·425 to 0·474	High	45	0·4492	0·0383	0·560	94,174	...	...
	Low	41	0·4490	0·0368	0·476	91,465	...	...
	Diff.		**0·0002**	**0·0015**	**0·084**	**2,709**	**2539**	**302**
0·475 to 0·524	High	22	0·4970	0·0374	0·557	100,097	...	...
	Low	20	0·4948	0·0352	0·477	96,163	...	...
	Diff.		**0·0022**	**0·0022**	**0·080**	**3,934**	**3494**	**437**
0·525 to 0·574	High	4	0·5500	0·0383	0·518	104,248	...	...
	Low	4	0·5440	0·0325	0·473	100,445	...	...
	Diff.		**0·0060**	**0·0058**	**0·045**	**3,803**	**2623**	**583**
0·575 to 0·624	High	3	0·5827	0·0377	0·533	109,945	...	...
	Low	3	0·5897	0·0283	0·453	104,850	...	...
	Diff.		**0·0070**	**0·0094**	**0·080**	**5,095**	**4855**	**607**

but this increase is not the same with steels of different carbon. In steels containing more than 0·374 per cent. of carbon, each increase of 0·01 per cent. of manganese augments the tensile

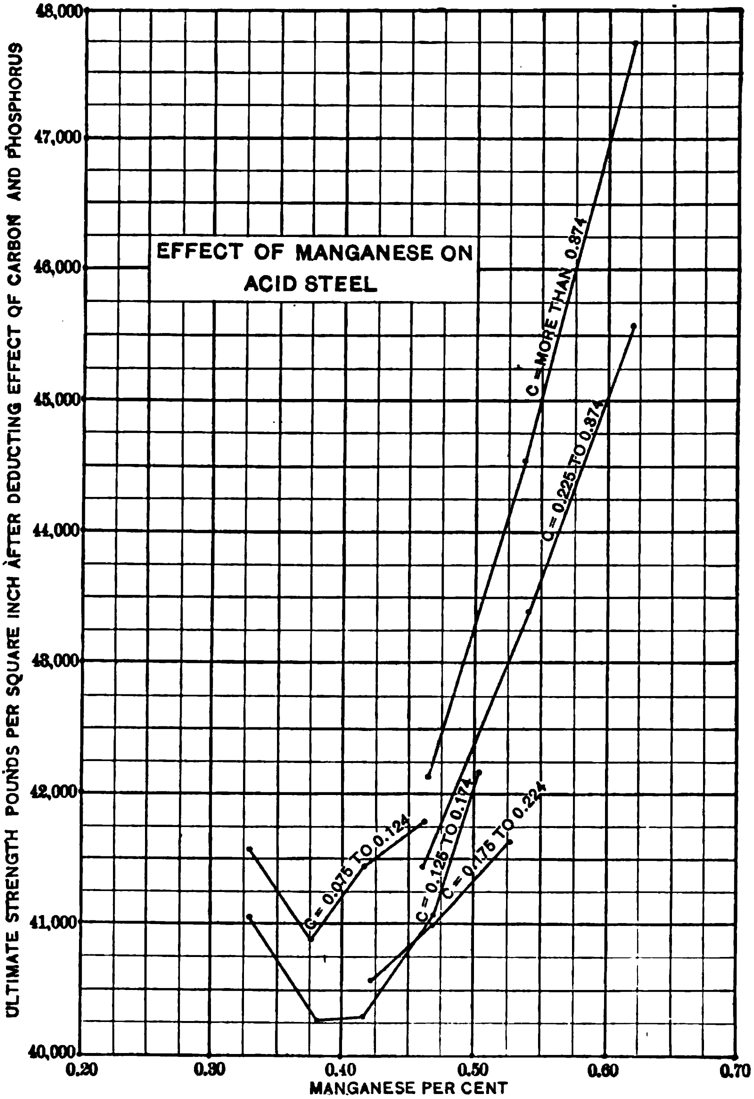

Fig. 3.—Effect of Manganese on Acid Steel.

strength by about 440 lbs. per square inch. In Table VI. it is shown that the average carbon of this group is about 0·44 per

TABLE VI.—*Classification of Acid Heats according to Content of Manganese.*

NOTE.—In the last column both carbon and phosphorus are valued at 1000 lbs. for 0·01 per cent.

Limits of Carbon.	Limits of Manganese.	Number of Heats.	Chemical Composition.				Ultimate Strength.	
			Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Records.	After Deducting for Carbon and Phosphorus.
Per Cent.	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
0·075 to 0·124	0·30 to 0·35	6	0·1052	0·0548	0·330	0·0560	57,558	41,558
	0·36 to 0·39	12	0·1117	0·0500	0·377	0·0576	57,047	40,877
	0·40 to 0·44	20	0·1110	0·0564	0·416	0·0589	58,173	41,433
	0·45 to 0·49	11	0·1168	0·0568	0·462	0·0636	59,135	41,775
0·125 to 0·174	0·30 to 0·35	2	0·1330	0·0585	0·330	0·0550	60,200	41,050
	0·36 to 0·39	19	0·1354	0·0538	0·381	0·0564	59,189	40,269
	0·40 to 0·44	55	0·1459	9·0569	0·417	0·0579	60,560	40,280
	0·45 to 0·49	41	0·1477	0·0564	0·470	0·0595	61,483	41,073
	0·50 to 0·59	14	0·1608	0·0601	0·503	...	64,253	42,163
0·175 to 0·224	0·40 to 0·44	16	0·2004	0·0562	0·422	0·0504	66,237	40,577
	0·45 to 0·49	23	0·2016	0·0587	0·468	0·0567	67,020	40,990
	0·50 to 0·59	19	0·1960	0·0579	0·527	...	67,035	41,645
0·225 to 0·374	0·40 to 0·49	47	0·3127	0 0476	0·461	...	77,471	41,441
	0·50 to 0·59	122	0·3305	0·0482	0·541	...	81,257	43,387
	0·60 to 0·69	19	0·3413	0·0476	0·618	...	84,463	45,573
Over 0·374	0·40 to 0·49	83	0·4495	0·0359	0·465	...	90,680	42,140
	0·50 to 0·59	144	0·4387	0·0395	0·537	...	92,365	44,545
	0·60 to 0·69	17	0·4461	0·0387	0·618	...	96,218	47,738

cent., and we thus determine that for a steel of 0·44 per cent. of carbon, the strengthening effect of 0·01 per cent. of manganese is about 440 lbs. per square inch. In the same way the line of next lower carbon shows that in steels of 0·33 per cent. of carbon, the strengthening effect is about 260 lbs. per square inch. The next three lines may be considered as a unit indicating that for steels of 0·155 per cent. of carbon, the strengthening effect is about 125 lbs. per square inch. Plotting these data it was found that the strengthening effect of each 0·01 per cent. of manganese above a content of 0·4 per cent. is 80 lbs.

per square inch for a steel of 0·1 per cent. of carbon, but that for each rise of 0·01 per cent. of carbon the strengthening effect is increased 8 lbs. Thus an increase in manganese from 0·4 to 0·41 per cent. in steel of 0·1 per cent. of carbon raises the strength 80 lbs., but an increase in manganese from 0·4 to 0·41 per cent. in steel of 0·11 per cent. of carbon raises the strength 88 lbs. A continuation of the line thus plotted gave zero effect for zero carbon. With basic steel it will appear that a different value was obtained for a starting point and a different value for the increment. The law of variation in the effect of manganese upon acid steels is shown in Table VII.

TABLE VII.—*Effect of Manganese upon Acid Steel.*

Carbon.	Manganese.										
	Per Cent. 0·40	Per Cent. 0·42	Per Cent. 0·44	Per Cent. 0·46	Per Cent. 0·48	Per Cent. 0·50	Per Cent. 0·52	Per Cent. 0·54	Per Cent. 0·56	Per Cent. 0.58	Per Cent. 0·60
Per Cent.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.
0·10	...	160	320	480	640	800	960	1120	1280	1440	1600
0·15	...	240	480	720	960	1200	1440	1680	1920	2160	2400
0·20	...	320	640	960	1280	1600	1920	2240	2560	2880	3200
0·25	...	400	800	1200	1600	2000	2400	2800	3200	3600	4000
0·30	...	480	960	1440	1920	2400	2880	3360	3840	4320	4800
0·35	...	560	1120	1680	2240	2800	3360	3920	4480	5040	5600
0·40	...	640	1280	1920	2560	3200	3840	4480	5120	5760	6400
0·45	...	720	1440	2160	2880	3600	4320	5040	5760	6480	7200
0·50	...	800	1600	2400	3200	4000	4800	5600	6400	7200	8000
0·55	...	880	1760	2640	3520	4400	5280	6160	7040	7920	8800
0·60	...	960	1920	2880	3840	4800	5760	6720	7680	8640	9600

EFFECT OF SULPHUR ON ACID STEEL.

First Method.—The heats were divided into high and low sulphur as shown in Table VIII., following the same system as used with manganese and phosphorus. The results give a value of minus 100 lbs. for 0·01 per cent. of sulphur, indicating that 0·01 per cent. weakens the steel by 100 lbs. per square inch.

Second Method.—The heats were classified according to their sulphur-content, the results being shown in Table IX. and in Fig. 4. The second method corroborates the first in showing that sulphur has little influence upon the strength of acid steel.

TABLE VIII.—*Division of Heats to Determine the Effect of Sulphur on Acid Steel.*

NOTE.—In the eighth column both carbon and phosphorus are valued at 1000 lbs. for 0·01 per cent.; the figure for manganese is taken from Table VII.

		Chemical Composition.				Ultimate Strength.				
Limits of Carbon.	Relative Sulphur.	Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Records.	Difference due to Sulphur alone.	Effect of 0·01 Per Cent. of Sulphur.	Number of Heats.	Product of Last Two Columns.
Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.		
0·075 to 0·124	High	0·1154	0·0587	0·424	0·0657	58,860	...	...	...	...
	Low	0·1079	0·0501	0·390	0·0523	57,093	...	...	...	...
	Diff.	**0·0075**	**0·0086**	**0·034**	**0·0134**	**1,767**	**−143**	**−107**	**50**	**−5,350**
0·125 to 0·174	High	1·1467	0·0600	0·439	0·0640	61,582	...	...	...	...
	Low	0·1485	0·0526	0·435	0·0509	60,398	...	...	...	...
	Diff.	**0·0018**	**0·0074**	**0·004**	**0·0131**	**1,184**	**+576**	**+440**	**131**	**+57,640**
0·175 to 0·224	High	0·2001	0·0604	0·488	0·0628	67,482	...	...	...	...
	Low	0·1987	0·0553	0·462	0·0490	66,181	...	...	...	...
	Diff.	**0·0014**	**0·0051**	**0·026**	**0·0138**	**1,301**	**+235**	**+170**	**58**	**+9,860**
0·225 to 0·274	High	0·2490	0·0596	0·486	0·0576	70,925	...	...	...	...
	Low	0·2435	0·0530	0·483	0·0488	70,550	...	...	...	...
	Diff.	**0·0055**	**0·0066**	**0·003**	**0·0088**	**375**	**−895**	**−1017**	**22**	**−22,374**
0·275 to 0·324	High	0·3067	0·0526	0·538	0·0597	79,650	...	...	...	...
	Low	0·3062	0·0419	0·517	0·0475	78,363	...	...	...	...
	Diff.	**0·0005**	**0·0107**	**0·021**	**0·0122**	**1,287**	**−337**	**−276**	**50**	**−13,800**
0·325 to 0·374	High	0·3499	0·0496	0·546	0·0574	83,526	...	...	...	...
	Low	0·3503	0·0432	0·527	0·0460	82,615	...	...	...	...
	Diff.	**0·0004**	**0·0064**	**0·019**	**0·0114**	**911**	**−221**	**−194**	**120**	**−23,280**
0.375 to 0·424	High	0·3993	0·0437	0·527	0·0543	87,475	...	...	...	...
	Low	0·4007	0·0363	0·509	0·0424	86,830	...	...	..	...
	Diff.	**0·0014**	**0·0074**	**0·018**	**0·0119**	**645**	**−531**	**−446**	**103**	**−45,938**
0·425 to 0·474	High	0·4522	0·0418	0·529	0·0551	93,721	...	...	...	...
	Low	0·4462	0·0336	0·512	0·0413	92,082	...	...	...	...
	Diff.	**0·0060**	**0·0082**	**0·017**	**0·0138**	**1,639**	**−393**	**−285**	**86**	**−24,510**
0·475 to 0·524	High	0·4944	0·0380	0·518	0·0519	97,911	...	...	...	...
	Low	0·4975	0·0347	0·520	0·0426	98,536	...	...	...	...
	Diff.	**0·0031**	**0·0033**	**0·002**	**0·0093**	**−625**	**−565**	**−608**	**42**	**−25,536**
0·525 to 0·574	High	0·5421	0·0405	0·500	0·0510	103,665	...	...	...	...
	Low	0·5517	0·0302	0·490	0·0422	101,027	...	...	...	...
	Diff.	**0·0096**	**0·0103**	**0·010**	**0·0088**	**2,638**	**+2128**	**+2418**	**8**	**+19,344**
0·575 to 0·624	High	0·5897	0·0300	0·507	0·0503	108,550	...	...	...	...
	Low	0·5827	0·0360	0·480	0·0417	106,245	...	...	...	...
	Diff.	**0·0070**	**0·0060**	**0·027**	**0·0086**	**2,305**	**+952**	**+1107**	**6**	**+6,642**
			Total .	.	.	.	.	.	676	−67,302
			Average .	.	.	.	.	.	.	−100

TABLE IX.—*Classification of Acid Heats according to Content of Sulphur.*

NOTE.—In the last column a value of 1000 lbs. is given to 0·01 per cent. of both carbon and phosphorus; the figure for manganese is taken from Table VII.

Limits of Carbon.	Number of Heats.	Chemical Composition.				Ultimate Strength.	
		Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Records.	After Deducting for Carbon, Phosphorus, and Manganese.
Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
0·075 to 0·224	58	0·1601	0·0519	0·425	0·0474	61,689	40,169
	68	0·1457	0·0546	0·444	0·0547	61,097	40,561
	61	0·1551	0·0581	0·448	0·0602	62,376	40,486
	52	0·1474	0·0621	0·444	0·0703	62,195	40,717
0·225 to 0·374	44	0·3345	0·0401	0·518	0·0431	80,478	39,903
	37	0·3288	0·0470	0·527	0·0495	80,798	39,865
	60	0·3256	0·0499	0·533	0·0544	80,670	39,609
	51	0·3203	0·0532	0·535	0·0612	80,582	39,776
0·375 to 0·524	63	0·4356	0·0330	0·514	0·0389	90,689	39,816
	45	0·4419	0·0367	0·511	0·0454	92,041	40,274
	64	0·4378	0·0392	0·515	0·0500	90,988	39,240
	59	0·4290	0·0449	0·536	0·0579	91,726	39,658

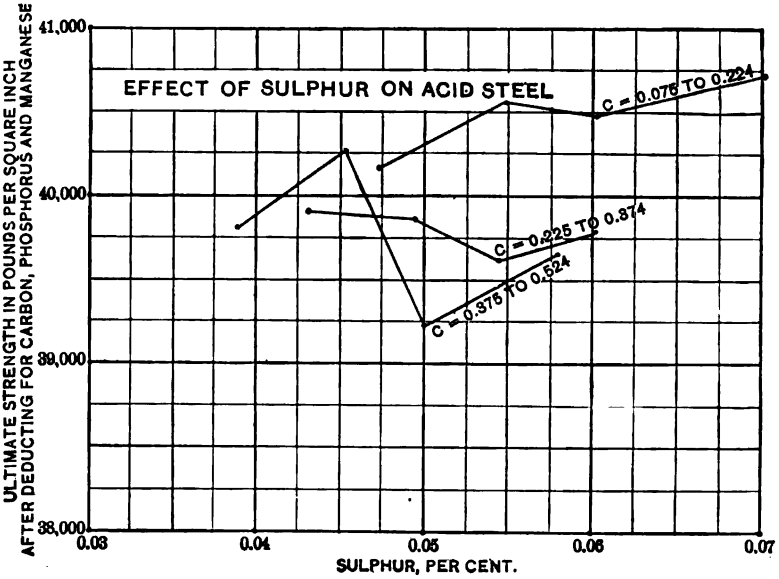

FIG. 4.—Effect of Sulphur on Acid Steel,

EFFECT OF CARBON ON ACID STEEL.

Having found the effect of manganese and phosphorus, it becomes possible to correct the original line so as to determine the value of carbon. It so happens that the heats of higher carbon are at the same time of higher manganese. This makes a double correction, as an allowance must be made for the greater amount of manganese and for the greater effect of this element in steels of higher carbon. The allowances are made in accordance with Table VII. The result is to drop the upper end of the line more than the lower and thereby decrease the angle which the line makes with the horizontal, this angle measuring the effect of carbon.

In allowing for phosphorus very little change is made in

TABLE X.—*Effect of Carbon upon Acid Steel.*

NOTE.—In calculating the last column a value of 1000 lbs. is given to 0·01 per cent. of phosphorus; manganese is rated according to Table VII.

Class.	Chemical Composition.			Ultimate Strength.	
	Carbon.	Phosphorus.	Manganese.	Actual Records.	After Deducting for Phosphorus and Manganese.
	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Acid test-bars; carbon by combustion.	0·1520	0·0565	0·440	61,806	55,676
	0·1713	0·0570	0·453	63,637	57,216
	0·2486	0·0537	0·497	72,185	64,875
	0·3268	0·0480	0·529	80,626	72,472
	0·3609	0·0443	0·528	83,886	75,744
	0.3943	0·0419	0·526	87,155	78,996
	0·4357	0·0384	0·519	91,278	83,273
	0·4693	0·0371	0·518	95,052	86,917
	0·5130	0·0358	0·513	99,795	91,605
Acid test-bars; carbon by colour.	0·1489	0·0562	0·443	63,072	56,936
	0·1600	0·0564	0·453	64,379	58,061
	0·2437	0·0541	0·491	72,980	65,823
	0·3255	0·0434	0·519	83,168	75,686
	0·3534	0·0403	0·515	87,012	79,762
	0·3827	0·0364	0·513	90,742	83,667
	0·4112	0·0351	0·506	94,689	87,702

this angle, as the proportion of phosphorus is nearly the same in the low- and in the high-carbon steels, but the whole line is lowered, thereby giving a lower value for the point where the prolongation of the line intersects the ordinate of zero carbon. Table X. gives the corrected values which are plotted in Figs. 5 and 6. The lines AA and BB are copied from Fig. 1; the lines A_2A_2 and B_2B_2 represent the allowance for manganese, and the lines A_3A_3 and B_3B_3 are corrected for both manganese and phosphorus. The line A_3A_3 indicates a value of 1000 lbs. for each 0·01 per cent. of carbon, when the combustion method is used, and it intersects the zero ordinate at 40,000 lbs. The line B_3B_3 indicates a value of 1140 lbs. for each 0·01 per cent. of

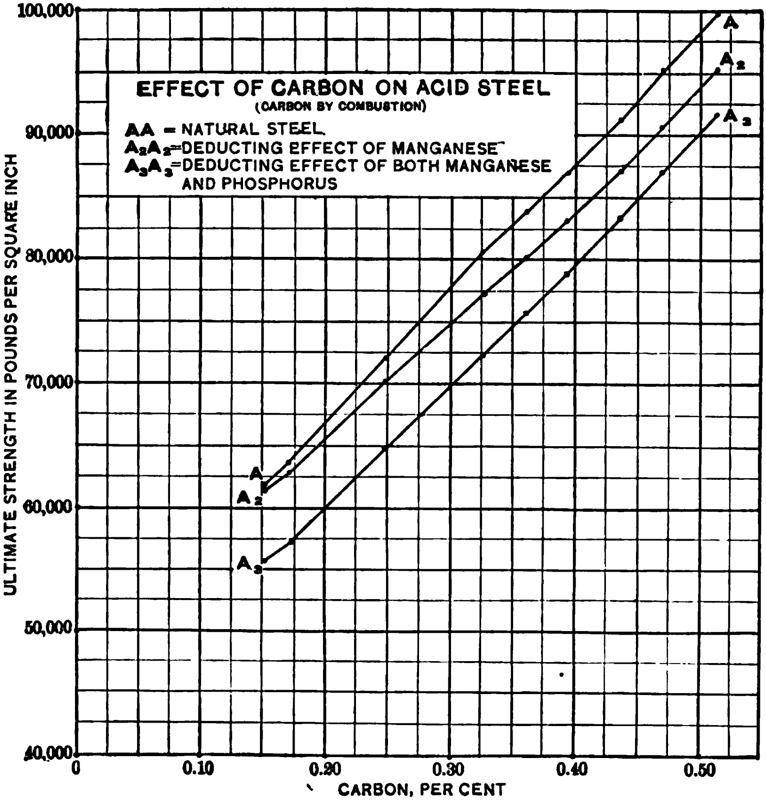

FIG. 5.—Effect of Carbon on Acid Steel (Carbon by Combustion).

carbon, when the colour method is used, and it intersects the zero ordinate at 39,800 lbs.

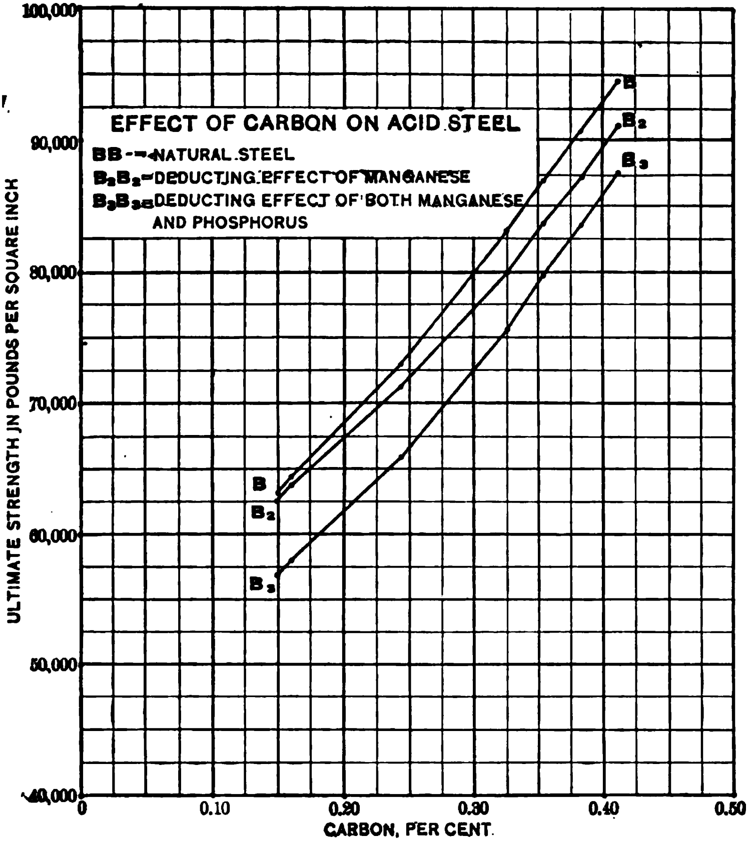

Fig. 6.—Effect of Carbon on Acid Steel (Carbon by Colour).

Effect of Manganese on Basic Steel.

First Method.—The bars were divided into high- and low-manganese as shown in Table XI. The figures show an increasing value for manganese as the carbon increases, thereby agreeing with the work on acid steel. In the first group, composed of heats of very soft steel, the value of manganese is practically zero. This is the same thing as saying that the decrease in manganese-content from 0·408 per cent. to 0·118 per cent. did not decrease the strength, which is entirely in accord with the theory before advanced that oxide of iron strengthens steel.

TABLE XI.—*Division of Heats to Determine the Effect of Manganese upon Basic Steel.*

NOTE.—In the eighth column a value of 770 lbs. is given to 0·01 per cent. of carbon, and 1000 lbs. to 0·01 per cent. of phosphorus.

Limits of Carbon.	Relative Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.		
			Carbon.	Phosphorus.	Manganese.	Actual Records.	Difference due to Manganese alone.	Effect of 0·01 Per Cent. of Manganese.
Per Cent.			Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.
0·020 to 0·074	High	58	0·0622	0·0094	0·408	48,152	...	...
	Low	77	0·0322	0·0073	0·118	45,669	...	...
			0·0300	**0·0021**	**0·290**	**2,483**	**– 37**	**–1**
0·075 to 0·124	High	64	0·0968	0·0086	0·485	50,726	...	...
	Low	61	0·0980	0·0083	0·357	49,445	...	...
			0·0012	**0·0003**	**0·128**	**1,281**	**1177**	**92**
0·125 to 0·174	High	68	0·1555	0·0121	0·497	56,680	...	...
	Low	66	0·1488	0·0112	0·374	54,887	...	...
			0·0067	**0·0009**	**0·123**	**1,793**	**1003**	**82**
0·175 to 0·224	High	120	0·2049	0·0130	0·535	62,370	...	...
	Low	126	0·2040	0·0097	0·411	60,162	...	...
			0·0009	**0·0033**	**0·124**	**2,208**	**1598**	**129**
0·225 to 0·274	High	128	0·2495	0·0123	0·532	67,058	...	...
	Low	135	0·2474	0·0098	0·415	62,528	...	...
			0·0021	**0·0025**	**0·117**	**4,530**	**3896**	**333**
0·275 to 0·324	High	60	0·2907	0·0123	0·525	69,593	...	...
	Low	65	0·2960	0·0090	0·408	67,144	...	...
			0·0053	**0·0033**	**0·117**	**2,449**	**2286**	**195**
0·325 to 0·374	High	14	0·3414	0·0099	0·516	73,116	...	...
	Low	13	0·3411	0·0126	0·401	70,932	...	...
			0·0003	**0·0027**	**0·115**	**2,184**	**2171**	**189**
0·375 to 0·424	High	6	0·3938	0·0150	0·583	82,695	...	...
	Low	5	0·3924	0·0080	0·398	73,741	...	...
			0·0014	**0·0070**	**0·185**	**8,954**	**7691**	**416**

Second Method.—The bars were classified according to their content of manganese as shown in Table XII. and in Fig. 7. The line of very low-carbon and low-manganese steels shows that in the absence of manganese the strength is raised by iron oxide or by some other agent. In steels of higher carbon less oxygen is present owing to the protecting power of carbon, and the decrease in strength with decrease in manganese holds good down to a content of 0·3 per cent. Considering only the

TABLE XII.—*Classification of Basic Heats according to Content of Manganese.*

NOTE.—In the last column a value of 770 lbs. is given to 0·01 per cent. of carbon, and 1000 lbs. to 0·01 per cent. of phosphorus.

Limits of Carbon.	Limits of Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.	
			Carbon.	Phosphorus.	Manganese.	Actual Records.	After Deducting for Carbon and Phosphorus.
Per Cent.	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Below 0·075	0·05 to 0·09	12	0·0297	0·0075	0·081	45,803	42,766
	0·10 to 0·14	56	0·0327	0·0073	0·120	45,674	42,426
	0·15 to 0·29	13	0·0388	0·0072	0·191	45,961	42,254
	0·30 to 0·39	61	0·0608	0·0097	0·354	48,034	42,390
	0·40 to 0·49	34	0·0632	0·0091	0·438	47,981	42,205
	0·50 to 0·59	4	0·0663	0·0133	0·508	51,133	44,698
0·075 to 0·224	0·20 to 0·29	7	0·1103	0·0079	0·259	50,056	40,773
	0·30 to 0·39	114	0·1458	0·0098	0·363	54,110	41,904
	0·40 to 0·49	242	0·1668	0·0099	0·441	57,036	43,203
	0·50 to 0·59	110	0·1744	0·0125	0·531	59,316	44,638
	0·60 to 0·69	26	0·1887	0·0154	0·622	61,862	45,793
0·225 to 0·374	0·30 to 0·39	61	0·2678	0·0089	0·365	63,858	42,349
	0·40 to 0·49	221	0·2689	0·0101	0·446	65,949	44,236
	0·50 to 0·59	102	0·2668	0·0130	0·532	67,565	45,723
	0·60 to 0·69	28	0·2695	0·0139	0·624	69,467	47,327

lines representing steels with from 0·075 to 0·224 per cent. and with from 0·225 to 0·374 per cent. of carbon, and pursuing the same course of reasoning as explained in the valuation of manganese in acid steels, it appears that above the limit of 0·3 per cent. of manganese, the effect of each unit of that element is greater in the steels of higher carbon. In the acid steel the value at zero carbon was zero, the effect of 0·01 per cent. of manganese in a steel of 0·1 per cent. of carbon was 80 lbs., and this effect increased 8 lbs. with each rise of 0·01 per cent. of carbon.

In basic steel the value of 0·01 per cent. of manganese at zero carbon is 90 lbs.; the effect per 0·01 per cent. of manganese is 130 lbs., and the increase in effect due to a rise of 0·01 per cent. of carbon is only 4 lbs. In the acid steel the base is 0·4 per cent. of manganese; in the basic steel it is 0·3 per cent. The results are tabulated in Table XIII.

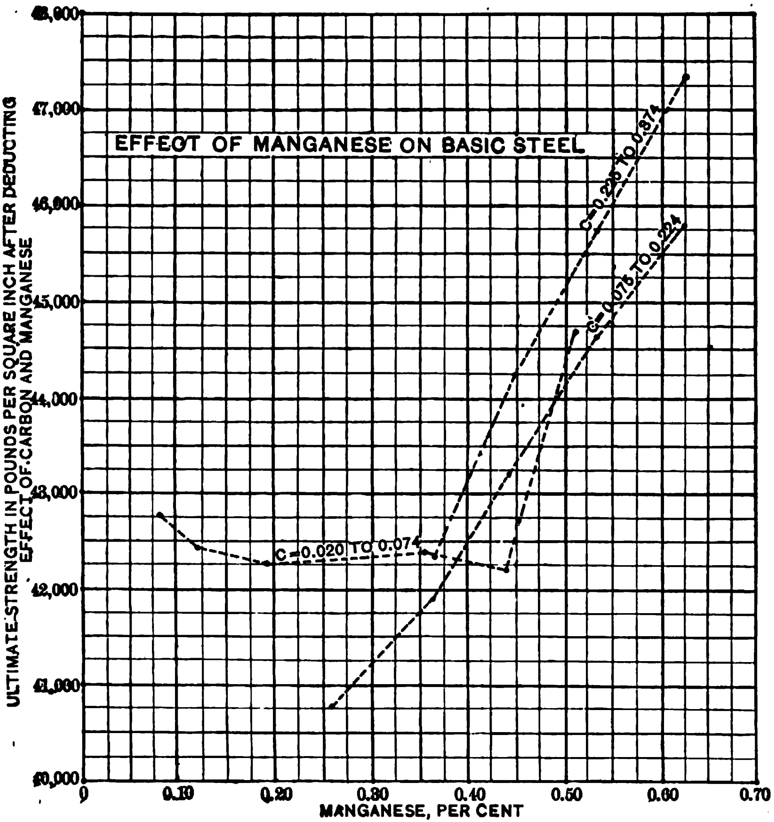

FIG. 7.—Effect of Manganese on Basic Steel.

TABLE XIII.—*Effect of Manganese upon Basic Steel.*

Carbon.	Manganese.						
	Per Cent. 0·30	Per Cent. 0·35	Per Cent. 0·40	Per Cent. 0·45	Per Cent. 0·50	Per Cent. 0·55	Per Cent. 0·60
Per Cent.		Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
0·05	...	550	1100	1650	2200	2750	3300
0·10	...	650	1300	1950	2600	3250	3900
0·15	...	750	1500	2250	3000	3750	4500
0·20	...	850	1700	2550	3400	4250	5100
0·25	...	950	1900	2850	3800	4750	5700
0·30	...	1050	2100	3150	4200	5250	6300
0·35	...	1150	2300	3450	4600	5750	6900
0·40	...	1250	2500	3750	5000	6250	7500

EFFECT OF SULPHUR UPON BASIC STEEL.

First Method.—The heats were divided into high- and low-sulphur, as shown in Table XIV., and the results indicate that

TABLE XIV.—*Division of Heats to Determine the Effect of Sulphur on Basic Steel.*

NOTE.—In the eighth column a value of 770 lbs. is given to 0·01 per cent. of carbon, and 1000 lbs. to 0·01 per cent. of phosphorus; manganese is rated as shown in Table XIII.

Limits of Carbon.	Relative Sulphur.	Chemical Composition				Ultimate Strength.			Number of Heats.	Product of Last Two Columns.
		Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Records.	Difference due to Sulphur alone.	Effect of 0·01 Per Cent. of Sulphur.		
Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	-Lbs. per Sq. Inch.	Lbs. per Sq. Inch.		
0·020	High	0·0545	0·0091	0·323	0·0353	47,512	...	...	...	...
to	Low	0·0361	0·0074	0·166	0·0240	46,000	...	*Note	...	...
0·074	**Diff.**	**0·0184**	**0·0017**	**0·157**	**0·0113**	**1,512**	**−74**	**−65**	**135**	**−8,775**
0·075	High	0·1012	0·0088	0·417	0·0452	51,070	...	...		...
to	Low	0·0936	0·0081	0·428	0·0267	49,116	...	...	...	...
0·124	**Diff.**	**0·0076**	**0·0007**	**0·011**	**0·0185**	**1,954**	**+1442**	**+779**	**125**	**+97,375**
0·125	High	0·1505	0.0133	0·428	0·0563	56,196	...	...	...	...
to	Low	0·1540	0·0099	0·446	0·0342	55,394	...	...	...	...
0·174	**Diff.**	**0·0035**	**0·0034**	**0·018**	**0·0221**	**802**	**+1002**	**+453**	**133**	**+60,250**
0·175	High	0·2038	0.0124	0·479	0·0553	61,236	...	...	...	...
to	Low	0·2050	0·0104	0·465	0·0356	61,247	...	...	...	...
0.224	**Diff.**	**0·0012**	**0·0020**	**0·014**	**0·0197**	**−11**	**−357**	**−181**	**246**	**−44,522**
0·225	High	0·2475	0·0132	0·487	0·0517	65,016		...	...	...
to	Low	0·2493	0·0089	0·457	0·0331	64,452	...	...	...	...
0·274	**Diff.**	**0·0018**	**0·0043**	**0·030**	**0·0186**	**564**	**−297**	**−160**	**263**	**−42,080**
0·275	High	0·2922	0·0120	0·477	0·0447	68,771	...	...	...	...
to	Low	0·2947	0·0092	0·451	0·0323	67,875	...	...	...	...
0·324	**Diff.**	**0·0025**	**0·0028**	**0·026**	**0·0124**	**896**	**+273**	**+220**	**125**	**+27,500**
0·325	High	0·3386	0·0128	0·450	0·0414	71,525	...	...	...	...
to	Low	0·3441	0·0093	0·472	0·0294	72,647	...	...	...	...
0·374	**Diff.**	**0·0055**	**0.0035**	**0·022**	**0·0120**	**−1,122**	**−551**	**−459**	**27**	**−12,392**
0·375	High	0·3950	0.0145	0·497	0·0397	78,400	...	...	...	...
to	Low	0·3910	0·0086	0·502	0·0308	78,895	...	...	...	...
0·424	**Diff.**	**0·0040**	**0·0059**	**0·005**	**0·0089**	**−495**	**−1270**	**−1427**	**11**	**+15,697**
				Total					1,065	+61,659
				Average						+58

* **NOTE.—In calculating the difference due to sulphur in the group of very low carbon steels, no allowance is made for the difference in manganese, as a decrease in manganese to a content of 0·166 per cent. is not necessarily followed by a decrease in strength.**

TABLE XV.—*Classification of Basic Heats according to Content of Sulphur.*

NOTE.—In the last column a value of 770 lbs. is given to 0·01 per cent. of carbon, and 1000 lbs. to 0·01 per cent. of phosphorus; manganese is rated as shown in Table XIII.

Limits of Carbon.	Number of Heats.	Chemical Composition.				Ultimate Strength.	
		Carbon.	Phosphorus.	Manganese.	Sulphur.	Actual Records.	After Deducting for Carbon, Phosphorus, and Manganese.
Per Cent.		Per Cent.	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Below 0·075	45	0·0361	0·0074	0·162	0·0225	45,978	42,458
	46	0·0418	0·0077	0·212	0·0283	46,337	42,348
	44	0·0575	0·0096	0·356	0·0380	47,922	41,896
0·075 to 0·224	74	0·1225	0·0078	0·434	0·0258	51,524	39,462
	103	0·1571	0·0089	0·444	0·0322	56,027	40,822
	112	0·1786	0·0114	0·446	0·0391	58,944	41,363
	105	0·1790	0·0115	0·461	0·0482	58,767	41,226
	110	0·1696	0·0129	0·441	0·0632	58,129	41,552
0·225 to 0·374	115	0·2754	0·0083	0·453	0·0298	66,333	41,206
	113	0·2693	0·0097	0·458	0·0365	66,194	41,360
	89	0·2679	0·0114	0·464	0·0434	66,307	41,292
	98	0·2582	0·0419	0·504	0·0563	66,334	41,005

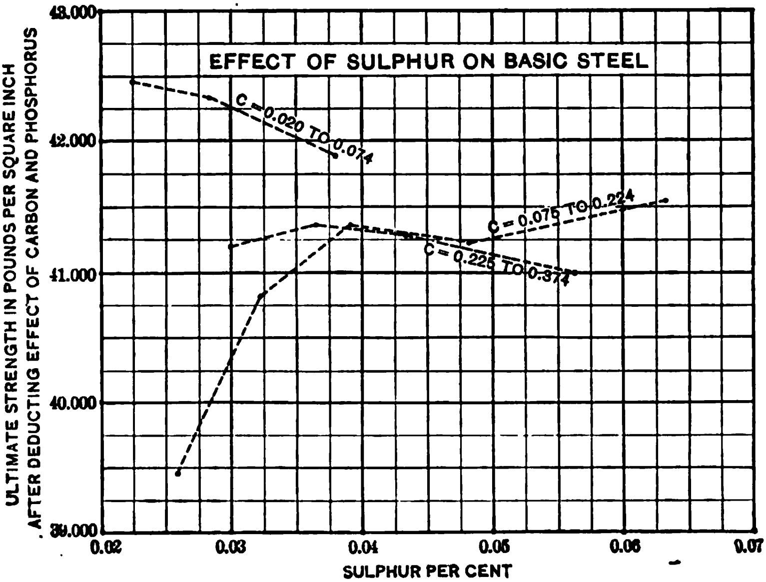

FIG. 8.—Effect of Sulphur on Basic Steel.

0·01 per cent. of sulphur strengthens steel by 58 lbs. per sq. inch. In the acid steel the same method of analysis showed a weakening effect of 100 lbs. In either case the value is too small to be important.

Second Method.—The heats were classified according to their sulphur-content, as shown in Table XV., and in Fig. 8. The lines are irregular and indeterminate, indicating a very small value for this element.

EFFECT OF CARBON UPON BASIC STEEL.

The effect of carbon was found, as in the case of acid steels, by allowing for phosphorus and manganese in the groups given in Table II. The data are given in Table XVI. and in Figs. 9 and 10. The line D_3D_8 indicates a value of 770 lbs. for each 0·01 per cent. of carbon when the combustion method is used and it intersects the zero ordinate at 41,500 lbs.

TABLE. XVI—*Effect of Carbon upon Basic Steel.*

NOTE.—In calculating the last column a value of 1000 lbs. is given to 0·01 per cent. of phosphorus; the manganese is rated as shown in Table XIII.

Class.	Chemical Composition.			Ultimate Strength.	
	Carbon.	Phosphorus.	Manganese.	Actual Records.	After Deducting for Phosphorus and Manganese.
	Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Basic test-bars; carbon by combustion.	0·0978	0·0094	0·366	50,834	49,036
	0·1639	0·0107	0·450	57,001	53,621
	0·210	0·0113	0·465	61,502	57,501
	0·241	0·0110	0·471	64,086	59,805
	0·268	0·0109	0·470	66,297	61,841
	0·3081	0·0108	0·466	69,626	64,994
	0·3582	0·0113	0·469	74,203	69,118
Basic test-bars; carbon by colour.	0·1010	0·0101	0·384	52,540	50,438
	0·1688	0·0116	0·458	59,739	56,083
	0·2036	0·0118	0·466	62,750	58,748
	0·2260	0·0118	0·468	64,839	60,601
	0·2564	0·0117	0·469	66,830	22,381

The line E_8E_8 indicates a value of 820 lbs. for each 0·01 per cent. of carbon when the colour-method is used, and it intersects the zero ordinate at 42,000 lbs.

It has already been explained, and is shown by Fig. 9, that any changes in the value of manganese affects the tangent of the carbon-line, thereby affecting the value found for a unit of that element; and as manganese has been given a slightly higher value in basic than in acid steel, it would naturally follow that the result for carbon would be lower in the basic than in the acid steel. To find how much this change in the value of manganese affected the carbon determination, the experiment was tried of correcting the line of basic, according to the values of

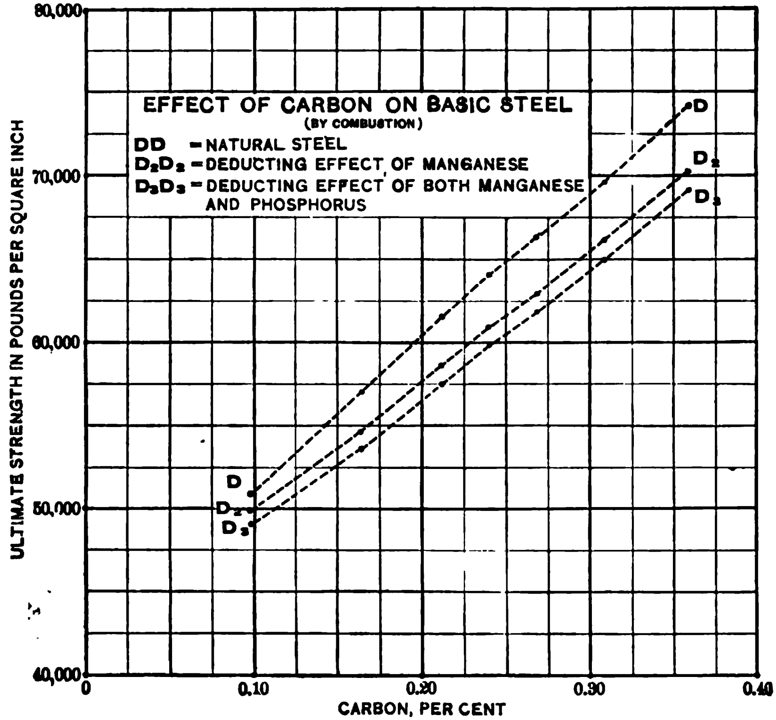

FIG. 9.—Effect of Carbon on Basic Steel (Carbon by Combustion).

manganese found for acid steel. The result showed a value of 810 lbs. for 0·01 per cent. of carbon instead of 770 lbs., as found by the above special investigation. Inasmuch as the acid steel gave a value for carbon of 1000 lbs. per unit of 0·01 per cent., and as the basic steel gives 810 lbs. when calculated by the acid formula and 770 lbs. by its own formula, it would seem certain that a unit of carbon has much less effect upon basic than upon acid steel.

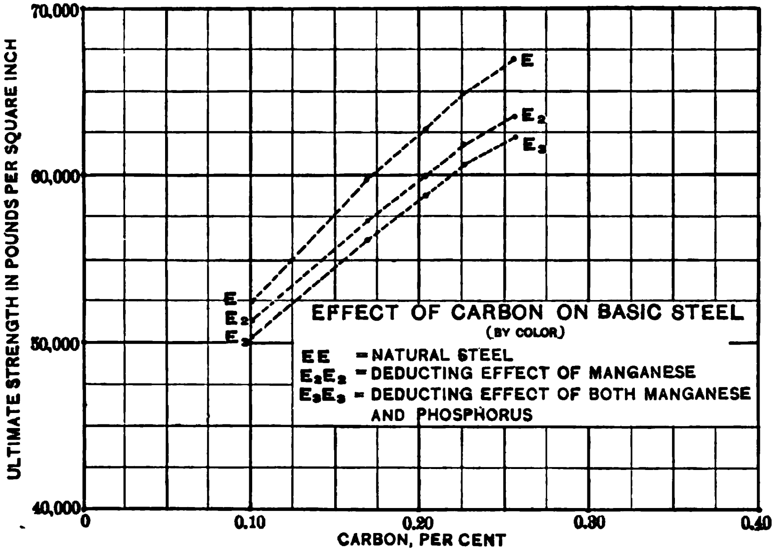

Fig. 10.—Effect of Carbon on Basic Steel (Carbon by Colour).

The Application of the Formulæ.

Table XVII. shows the result of comparing the actual strength of the steels under consideration with the strength as calculated from the formulæ just given. For this purpose the heats were grouped according to carbon and then subdivided according to manganese. No heats were put together that varied more than 0·05 per cent. in carbon, or more than 0·1 per cent. in manganese. For instance, a group might include

TABLE XVII.—*Comparison of the actual Ultimate Strength of certain Groups of Steel with the Strength as calculated from the following Formulæ:*

Acid steel: $40{,}000 + 1000\,C + 1000\,P + x\,Mn$ = ultimate strength.
Basic steel: $41{,}500 + 770\,C + 1000\,P + y\,Mn$ = ultimate strength.

Value of x as per Table VII.; value of y as per Table XIII.

Heavy type denotes that the difference between the actual and calculated strengths is over 1500 lbs.

Limits of Carbon.	Limits of Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.		
			Carbon.	Phosphorus.	Manganese	Actual Records.	By Formula.	Difference.
Per Cent.	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
Acid steel:								
0·075 to 0·124	0·30 to 0·39	18	0·1095	0·0517	0·361	57,217	56,120	−1097
	0·40 to 0·49	31	0·1131	0·0566	0·432	58,414	57,258	−1156
	0·50 to 0·59	1	0·1130	0·0440	0·500	56,745	56,600	−145
0·125 to 0·174	0·30 to 0·39	21	0·1352	0·0542	0·377	59,285	58,940	−345
	0·40 to 0·49	96	0·1466	0·0567	0·440	60,954	60,794	−160
	0·50 to 0·59	14	0·1608	0·0601	0·513	64,253	63,536	−717
0·175 to 0·224	0·40 to 0·49	39	0·2011	0·0577	0·449	66,698	66,664	−34
	0.50 to 0·59	19	0·1960	0·0579	0·527	67,035	67,371	+336
0·225 to 0·274	0·30 to 0·39	1	0·2340	0·0550	0·390	68,460	68,900	+440
	0·40 to 0·49	11	0·2520	0·0576	0·462	71,068	72,200	+1132
	0·50 to 0·59	10	0·2413	0·0551	0·519	70,602	71,925	+1323
0·275 to 0·324	0·40 to 0·49	14	0·3093	0·0446	0·469	78,200	77,101	−1099
	0·50 to 0·59	32	0·3066	0·0485	0·541	79,167	78,950	−217
	0·60 to 0·69	**3**	**0·2863**	**0·0497**	**0·613**	**80,223**	**78,456**	**−1767**
	0·70 to 0·79	**1**	**0·3240**	**0·0560**	**0·720**	**84,100**	**86,320**	**+2220**
0·325 to 0·374	**0·30 to 0·39**	**1**	**0·3490**	**0·0340**	**0·300**	**81,650**	**78,300**	**−3350**
	0·40 to 0·49	22	0·3452	0·0446	0·455	80,208	80,498	+290
	0·50 to 0·59	80	0·3512	0·0472	0·544	83,425	83,872	+447
	0·60 to 0·69	16	0·3516	0·0472	0·619	85,258	86,012	+754
	0·70 to 0·79	1	0·3440	0·0450	0·700	86,840	87,180	+340
0·375 to 0·424	0·40 to 0·49	34	0·4009	0·0377	0·464	85,205	85,908	+703
	0·50 to 0·59	63	0·3996	0·0410	0·537	87,880	88,444	+564
	0·60 to 0·69	6	0·3993	0·0425	0·622	90,598	91,284	+686
0·425 to 0·474	0·40 to 0·49	27	0·4481	0·0363	0·462	90,950	90,672	−278
	0·50 to 5·59	53	0·4515	0·0382	0·539	93,760	93,974	+214
	0·60 to 0·69	6	0·4332	0·0378	0·617	93,805	94,587	+782
0·475 to 0·524	0·30 to 0·39	1	0·4770	0·0330	0·380	90,775	91,000	+225
	0·40 to 0·49	12	0·4955	0·0340	0·468	95,745	95,643	−102
	0·50 to 0·59	25	0·4961	0·0376	0·533	98,699	98,637	−62
	0·60 to 0·69	**4**	**0·5010**	**0·0365**	**0·617**	**104,550**	**102,430**	**−2120**
0·525 to 0·574	0·40 to 0·49	6	0·5463	0·0303	0·478	100,718	101,061	+343
	0·50 to 0·59	2	0·5490	0·0505	0·545	107,230	106,330	−900
0·575 to 0·624	0·40 to 0·49	4	0·5887	0·0312	0·462	105,131	104,904	−227
	0·50 to 0·59	**1**	**0·5770**	**0·0430**	**0·510**	**112,760**	**107,071**	**−5689**
	0·60 to 0·69	1	0·5850	0·0300	0·600	111,100	110,860	−240

TABLE XVII.—(*continued*).

Limits of Carbon.	Limits of Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.		
			Carbon.	Phosphorus.	Manganese	Actual Records.	By Formula.	Difference.
Per Cent. Basic Steel:	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.	Lbs. per Sq. Inch.
0·020 to 0·074	0·00 to 0·09	12	0·0297	0·0075	0.081	45,803	44,537	−1266
	0·10 to 0·19	65	0·0326	0.0073	0·125	45,645	44,740	−905
	0·20 to 0·29	4	0·0543	0·0073	0·263	47,094	46,411	−683
	0·30 to 0·39	16	0·0608	0·0097	0·354	48,034	47,767	−267
	0·40 to 0·49	34	0·0632	0·0091	0·438	47,981	48,849	+868
	0·50 to 0·59	4	0·0663	0·0133	0·508	51,133	50,389	−744
0·075 to 0·124	**0·10 to 0·19**	**1**	**0·0990**	**0·0080**	**0·160**	**45,780**	**49,923**	**+4143**
	0·20 to 0·29	6	0·0993	0·0078	0·262	49,378	49,926	+548
	0·30 to 0·39	42	0·0983	0·0086	0·363	49,683	50,748	+1065
	0·40 to 0·49	**53**	**0·0955**	**0·0083**	**0·438**	**49,667**	**51,477**	**+1810**
	0·50 to 0·59	21	0·0998	0·0089	0·539	51,900	53,182	+1282
	0·60 to 0·69	2	0·0950	0·0085	0·660	55,773	54,345	−1428
0·125 to 0·174	0·10 to 0·19	1	0·1370	0·0070	0·160	52,295	52,749	+454
	0·30 to 0·39	41	0·1486	0·0107	0·359	54,738	54,897	+159
	0·40 to 0·49	64	0·1531	0·0114	0·445	55,800	56,596	+796
	0·50 to 0·59	24	0·1549	0·0130	0·535	57,050	58,300	+1250
	0·60 to 0·69	**3**	**0·1657**	**0·0213**	**0·640**	[illegible]	**61,693**	**+1750**
0·175 to 0·224	**0·20 to 0·29**	**1**	**0·1760**	**0·0080**	**0·240**	**54,120**	**55,852**	**+1732**
	0·30 to 0·39	31	0·2064	0.0104	0.367	59,276	59,611	+335
	0·40 to 0·49	125	0·2040	0.0098	0·441	60,752	60,670	−82
	0·50 to 0·59	65	0·2059	0·0135	0·527	62,547	62,698	+151
	0·60 to 0·69	21	0·2009	0·0152	0·616	62,716	63,987	+1271
	0·70 to 0·79	3	0·2050	0·0087	0·713	65,507	65,424	−83
0·225 to 0·274	0·20 to 0·29	1	0·2300	0·0070	0·260	61,090	59,909	−1181
	0·30 to 0·39	39	0·2458	0·0079	0·365	62,185	62,463	+287
	0·40 to 0·49	137	0·2489	0·0105	0·451	64,425	64,644	+219
	0·50 to 0·59	66	0·2490	0·0132	0·529	66,107	66,436	+329
	0·60 to 0·69	18	0·2495	0·0141	0·627	67,048	68,465	+1417
	0·70 to 0·79	**1**	**0·2740**	**0·0140**	**0·710**	**74,970**	**72,362**	**−2608**
	0·90 to 0·99	**1**	**0·2280**	**0·0150**	**0·940**	**67,595**	**72,395**	**+4800**
0·275 to 0·324	0·30 to 0·39	18	0·2986	0·0085	0·366	65,920	66,753	+833
	0·40 to 0·49	70	0·2937	0·0098	0·440	67,888	68,063	+175
	0·50 to 0·59	29	0·2907	0·0128	0·540	69,725	70.202	+477
	0·60 to 0·69	8	0·2900	0·0142	0·621	72,402	71,991	−411
0·325 to 0·374	0·30 to 0·39	4	0·3443	0·0200	0·355	70,954	71,286	+332
	0·40 to 0·49	14	0·3396	0·0086	0·437	71,170	71,660	+490
	0·50 to 0·59	7	0·3354	0·0114	0·524	72,365	73,572	+1207
	0·60 to 0·69	2	0·3675	0·0105	0·610	79,515	78,286	−1229
0·375 to 0·424	0·30 to 0·39	2	0·3830	0·0080	0·355	73,620	73,154	−466
	0·40 to 0·49	5	0·3936	0·0102	0·448	75,107	76,555	+1448
	0·50 to 0·59	**1**	**0·3860**	**0·0100**	**0·500**	**79,750**	**77,280**	**−2470**
	0·60 to 0·69	**2**	**0·4065**	**0·0220**	**0·645**	**88,545**	**83,832**	**−4713**
	0·70 to 0·79	**1**	**0·3920**	**0·0080**	**0·750**	**85,260**	**83,732**	**−1528**

a heat containing 0·1 per cent. of carbon and 0·3 per cent. of manganese, and another heat containing 0·149 per cent. of carbon and 0·399 per cent. of manganese, but any heat of higher or lower carbon, or of higher or lower manganese than these extremes, would fall into another group. Inasmuch as the phosphorus did not vary through wide limits in any of the steels, each group may be looked upon as composed of heats that are practically alike in chemical composition, and which may properly be averaged to eliminate accidental errors.

In some of the subdivisions the number of heats is so small that these errors cloud the result. Especially in the steels of higher carbon it is desirable to have a large number of heats in the average, as it is difficult to get uniform results on a testing machine under usual working conditions when the bar has a strength of over 90,000 lbs. per square inch, and unfortunately it is in these high steels, and particularly in the groups with an unusual content of manganese, that only a small number of heats were on record. There are accordingly several instances where these small groups show a considerable difference between the actual and the calculated strength, but there seems to be no rule as to the difference, as other groups, either large or small, of the same class of steels give satisfactory results.

It is of course a matter of opinion as to what constitutes a fair agreement between the actual and the calculated strengths, but in the following comparison it will be assumed that the results of the formulæ should be within 1500 lbs. of the records of the testing machine. In the acid steels there are 12 groups containing less than 5 heats each. In 7 of these the calculated strength agrees with the actual strength within 1500 lbs. In 5 groups the difference is over 1500 lbs. In the basic steel there are 17 groups containing less than 5 heats and 9 of these agree within 1500 lbs. Eight groups show a difference greater than this amount. Taking both acid and basic steels, out of 29 "small" groups 16 are correct, and of the 13 that are beyond the limit 9 are single heats, most of them being steel of moderately high carbon.

In the acid steel there are 23 groups containing over 4 heats each, and all of them are within the limit of 1500 lbs., only 5 having an error of over 1000 lbs. In the basic steel there are 26 groups with over 4 heats and 25 are within 1500 lbs., and 17 within 1000 lbs. There is 1 group of 53 heats averaging about 0·1 per cent. of carbon, which shows an error of +1810 lbs. Putting aside mathematical errors which can hardly be present in this investigation (owing to repeated checking of the totals at each separate rearrangement), it may appear probable that this

TABLE XVIII.—*Subdivision of the Groups in Table XVII. that contain over Fifty Heats, and are below* 0·225 *per cent. in Carbon, with special subdivision of the one large group showing a difference of more than* 1500 *lbs. between the actual and calculated strength.*

Limits of Carbon.	Limits of Manganese.	Number of Heats.	Chemical Composition.			Ultimate Strength.		
			Carbon.	Phosphorus.	Manganese.	Actual Records.	By Formula.	Difference.
Per Cent.	Per Cent.		Per Cent.	Per Cent.	Per Cent.	Lbs. per Sq. In.	Lbs. per Sq. In.	Lbs. per Sq. In.
Acid steel: 0·125 to 0·174	0·40 to 0·44	55	0·1459	0·0569	0·417	60,560	60,484	−76
	0·45 to 0·49	41	0·1477	0·0564	0·470	61,483	61,250	−233
Basic steel: 0·020 to 0·074	0·10 to 0·14	56	0·0327	0·0073	0·120	45,674	44,748	−926
	0·15 to 0·19	9	0·0319	0·0071	0·159	45,458	44,666	−792
0·075 to 0·124	0·40 to 0·44	33	0·0961	0·0086	0·418	49,809	51,294	+1485
	0·45 to 0·49	20	0·0946	0·0079	0·470	49,434	51,784	+2350
	0·40	12	0·0963	0·0075	0·400	48,949	50,965	+2016
	0·41	4	0·0888	0·0110	0·410	49,510	50,824	+1314
	0·42	5	0·0946	0·0080	0·420	49,469	51,096	+1627
	0·43	4	0·1012	0·0083	0·430	50,626	51,812	+1186
	0·44	8	0·0980	0·0091	0·440	51,053	51,776	+723
	0·45	4	0·0870	0·0078	0·450	48,521	50,869	+2348
	0·46	5	0·0922	0·0084	0·460	49,693	51,455	+1762
	0·47	3	0·0833	0·0073	0·470	48,383	50,718	+2335
	0·48	4	0·1135	0·0080	0·480	50,993	53,452	+2459
	0·49	4	0·0948	0·0075	0 490	49,253	51,982	+2729
0·125 to 0·174	0·40 to 0·44	32	0·1522	0·0114	0·418	55,495	56,129	+634
	0·45 to 0·49	32	0·1541	0·0114	0·473	56,265	57,102	+837
0·175 to 0·224	0·40 to 0·44	66	0·2036	0·0090	0·416	60,344	60,095	−249
	0·45 to 0·49	59	0·2046	0·0107	0·468	61,208	61,247	+39
	0·50 to 0·54	48	9·2063	0·0139	0·514	62,358	62,584	+226
	0·55 to 0·59	17	0·2049	0·0124	0·566	63,086	63,199	+113

group contains some abnormal bars, and it may also appear possible that some of the other large groups show an agreement through the averaging of bars showing wide differences among themselves.

Table XVIII. gives some information on this point. Every group in Table XVII. comprising more than 50 heats and containing less than 0·225 per cent. of carbon is subdivided so as to have only one-half the former variation in manganese. Thus, if a group comprised heats ranging from 0·4 to 0·49 per cent. of manganese, it is subdivided into one group ranging from 0·4 to 0·44 per cent., and another from 0·45 to 0·49 per cent. If the original group were an average of unlike units, it is probable that the fact would be made manifest by a wide difference between the two parts, but in no case is such a difference discernible.

In the case of the one group of 53 heats before-mentioned, a more extended analysis is given in the table. It has been divided into ten parts, the first containing only those heats that contained 0·4 per cent. of manganese, the second those with 0·41 per cent. of manganese, and so on. The number of heats in some of the subdivisions is small and complete regularity could hardly be expected, but in these ten subdivisions the smallest difference between the strength as calculated by the formula and the strength as found by the testing machine, is + 723 lbs., and the greatest is + 2729 lbs., so that the deviation of this group from the general rule is not due to one or two abnormal bars. With this one exception, the cause of which remains unexplained, all the large groups show a difference of less than 1500 lbs. between the actual and the calculated strength, which is perhaps as close an agreement as could be expected.

A careful analysis was made to discover whether anything could be learned from the so-called errors. If, for instance, the groups of low-carbon had shown a considerable and uniform minus error and the groups of high-carbon had uniformly shown a similar plus error, then it would be probable that the value of carbon was too high and the base too low. Investigation failed to show any regular law either for groups of high- and low-carbon, or for groups of high- and low-manganese.

The one fact which appears to be true of both acid and of basic steel is that the steels that are low in carbon and low in manganese are stronger than would be called for by the formula, and it seems probable that this is due to oxide of iron.

THE VALUE OF MANGANESE.

From Table XVII. may be obtained data which will corroborate the variable value assigned to manganese. The groups containing from 0·3 to 0·39 per cent. of manganese may be plotted, using as abscissas the percentage of carbon and as ordinates the ultimate strength. The groups containing from 0·4 to 0·49 per cent. of manganese furnish another line; those from 0·5 to 0·59 per cent. another; and those from 0·6 to 0·69 another. Owing to this subdivision many of the construction points in these lines represent only a small number of heats, and they have therefore been combined by groups of three as before explained. The result is shown in Table XIX. If the phosphorus in each group were constant, no allowance would have to be made for it; but since it varies considerably, the ultimate strength has been calculated to zero phosphorus, as shown in the last column of the table, and as plotted in Figs. 11 and 12.

In Fig. 11 it will be noted that the line of 0·4 to 0·49 per cent. manganese is slightly above the base line of 0·4 manganese, which is the limit already determined, below which a decrease in manganese does not weaken steel. The number of heats containing less than 0·4 per cent. of manganese in acid steel is small, and they are confined almost entirely to the two low-carbon groups, so that no line has been plotted for them; but if these two groups be put upon the diagram, it will be found that they are as strong as though the manganese were higher. Above the limit of 0·4 per cent. each increase in manganese raises the strength, and not only this, but the angle made with the horizontal is greater as the content of carbon increases. The lines tend to converge at the left of the figure at about 40,000 lbs., which has been found to be the base for acid steel; and they tend to spread as they go to the right, which

TABLE XIX.—*Classification of Groups in Table XVII. according to Manganese and Combination in Units of Three.*

Kind of Steel and Composition.	Chemical Composition.			Ultimate Strength.	
	Carbon.	Phosphorus.	Manganese.	Actual Records.	Deducting Effect of Phosphorus.
	Per Cent.	Per Cent.	Per Cent.	Lbs. per Square Inch.	Lbs. per Square Inch.
Acid steel; Mn =0·4 to 0·49 per cent. Line AA, Fig. 11.	0·1532	0·0569	0·441	61,840	56,180
	0·1691	0·0570	0·444	63,250	57,550
	0.2335	0·0548	0·456	69,963	64,483
	0·3127	0·0476	0·461	77,465	72,705
	0·3651	0·0412	0·462	82,238	78,118
	0·4004	0·0391	0·461	85,750	81,840
	0·4339	0·0366	0·464	89,060	85,400
	0·4738	0·0349	0·466	93,528	90,038
	0·5264	0·0325	0·470	98,860	95,610
Acid steel; Mn =0·5 to 0·59 per cent. Line BB, Fig. 11.	0·1791	0·0584	0·520	65,590	59,750
	0·1951	0·0580	0·521	66,962	61,162
	0·2614	0·0525	0·533	73,985	68,735
	0·3305	0·0482	0·541	81,259	76,439
	0·3605	0·0452	0·541	84,250	79,730
	0·3938	0·0428	0·540	87,650	83,370
	0·4361	0·0394	0·537	92,030	88,090
	0·4679	0·0383	0·537	95,640	91,810
	0·5028	0·0387	0·533	99,800	95,930
Acid steel; Mn =0·6 to 0·69 per cent. Line CC, Fig. 11.	0·3553	0·0463	0·619	85,940	81,310
	0·3793	0·0442	0·619	88,240	83,820
	0·4374	0·0392	0·619	95,280	91,360
	0·4716	0·0366	0·615	99,280	95,620
Basic steel; Mn =0·3 to 0·39 per cent. Line AA, Fig. 12.	0·1131	0·0097	0·360	51,505	50,535
	0·1458	0·0098	0·363	54,107	53,127
	0·1989	0·0096	0·363	58,620	57,660
	0·2427	0·0089	0·366	61,900	61,010
	0·2678	0·0089	0·365	63,860	62,970
	0·3132	0·0104	0·363	67,397	66,357
Basic steel; Mn =0·4 to 0·49 per cent. Line BB, Fig. 12.	0·1127	0·0098	0·441	51,920	50,940
	0·1668	0·0099	0·441	57,040	56,050
	0·2129	0·0104	0·446	61,340	60,300
	0·2415	0·0101	0·445	63,775	62,765
	0·2689	0·0101	0·446	65,955	64,945
	0·3065	0·0096	0·440	68,807	67,847
Basic steel; Mn =0·5 to 0·59 per cent. Line CC, Fig. 12.	0·1240	0·0112	0·534	54,360	53,240
	0·1745	0·0125	0·531	59,315	58,065
	0·2163	0·0133	0·529	63,210	61,880
	0·2390	0·0133	0·530	65.315	63,985
	0·2667	0·0130	0·532	67,560	66,260
	0·3018	0·0125	0·536	70,495	69,245
Basic steel; Mn =0·6 to 0·69 per cent. Line DD, Fig. 12.	0·1887	0·0154	0·622	61,864	60,324
	0·2192	0·0151	0·622	64,373	62,863
	0·2347	0·0146	0·621	66,020	64,560
	0·2695	0·0139	0·624	69,465	68,075
	0·3223	0·0149	0·623	76,278	74,788

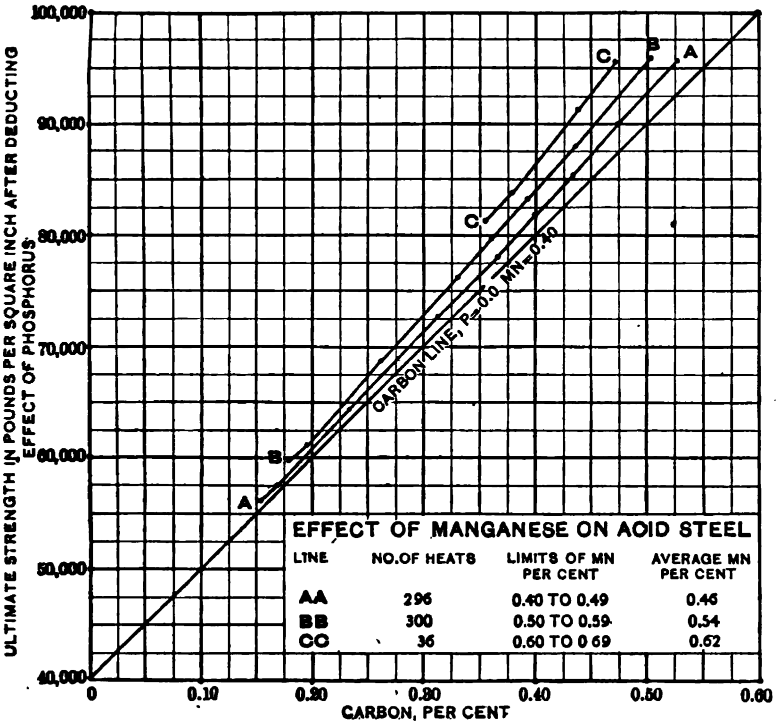

FIG. 11.—Effect of Manganese on Acid Steel.

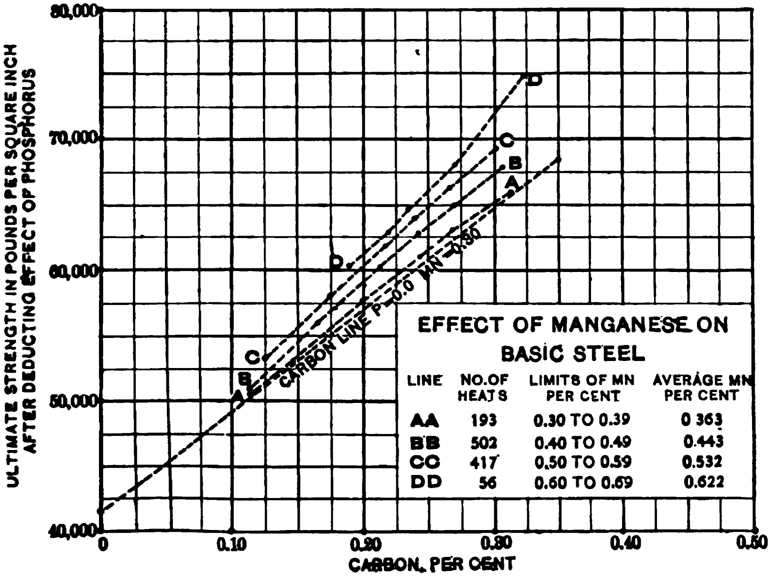

FIG. 12.—Effect of Manganese on Basic Steel.

shows that the strengthening effect of manganese increases as the content of carbon increases, and it is possible to estimate the effect by noting at what point a prolongation of these lines will give a given ordinate, say the ordinate of 0·60 per cent. carbon. It is estimated that the line AA will cut this ordinate at 103,000 lbs., and it is known that according to the formula for acid steel the strength of steel of 0·60 per cent. carbon and 0·40 per cent. manganese would be 100,000 lbs. There is therefore an increase in strength of 3000 lbs. due to the amount of manganese in excess of 0·40 per cent. In Table XIX. it will be seen that the average manganese of the line AA is about 0·46 per cent., so that the strengthening effect of manganese in a steel of 0·60 per cent. carbon, as shown by this one line, is 500 lbs. for each 0·01 per cent. In a similar way the line BB gives a value of 429 lbs., and the line CC 454 lbs.

The variation in values does not represent any law, but arises from determinative errors and the results should therefore be averaged. The line AA represents 296 heats, BB 300 heats, and CC 36 heats, so that the true average is 464 lbs. for the influence of 0·01 per cent. of manganese upon a steel of 0·60 per cent. carbon. In Table VII. the corresponding figure was 480 lbs.

The results from the basic steel are plotted in Fig. 12, the base being 0·30 per cent. manganese instead of 0·40 per cent. as in acid metal. It will be evident that the same law holds good that the effect of manganese increases with higher carbons. An analysis according to the same method used in the acid steels gave a value for 0·01 per cent. of manganese of 200 lbs. for a steel of 0·35 per cent. carbon, when Table XIII. calls for 234 lbs. In both the acid and the basic steels the agreement is all that could be expected, so that it would seem that in the steels under consideration the manganese has a value varying with the amount of carbon present.

CONCLUSIONS.

Carbon.—In acid steel each 0·01 per cent. of carbon strengthens steel by 1000 lbs. per square inch when the carbon is determined by combustion. The strengthening effect is 1140 lbs. for each 0·01 per cent. as determined by colour, owing to the fact that the colour test does not determine all the carbon present.

In basic steel each 0·01 per cent. of carbon strengthens steel by 770 lbs. per square inch when the carbon is determined by combustion. The strengthening effect is 820 lbs. for each 0·01 per cent. as determined by colour.

Phosphorus.—Each 0·01 per cent. of phosphorus strengthens steel by 1000 lbs. per square inch.

Manganese.—Each 0·01 per cent. of manganese has a strengthening effect upon steel, and the effect is greater as the content of carbon increases. Below a certain content of manganese the effect is complicated by some disturbing condition, probably iron oxide, so that a decrease in manganese in very low-carbon steels is accompanied by an increase in strength. In acid steel each increase of 0·01 per cent. in manganese above 0·4 per cent. raises the strength of acid steel an amount varying from 80 lbs. in a metal containing 0·1 per cent. carbon to 400 lbs. in a metal containing 0·4 per cent. carbon. In basic steel each increase above 0·3 per cent. raises the strength an amount varying from 130 lbs. in a metal containing 0·1 per cent. of carbon to 250 lbs. in a metal containing 0·4 per cent. of carbon.

Sulphur.—The effect of sulphur on the strength of acid and of basic steel is very small.

Formulæ.—From the foregoing results, the following formulæ may be written, in which C = 0·01 per cent. of carbon, P = 0·01 per cent. of phosphorus, Mn = 0·01 per cent. of manganese, R = a variable to allow for heat-treatment, and the answer is the ultimate strength in lbs. per square inch. The coefficient of manganese in acid steel, called *x*, is the value given in Table VII., and applies only to contents above 0·4 per cent. The value of manganese in basic steel, called *y*, is the value given in Table XIII., and applies to contents above 0·3 per cent.

Formula for acid steel, carbon by combustion:

$$40{,}000+1000\ C+1000\ P+x\ Mn+R=\text{Ultimate strength.}$$

Formula for acid steel, carbon by colour:

$$39{,}800+1140\ C+1000\ P+x\ Mn+R=\text{Ultimate strength.}$$

Formula for basic steel, carbon by combustion:

$$41{,}500+770\ C+1000\ P+y\ Mn+R=\text{Ultimate strength.}$$

Formula for basic steel, carbon by colour:

$$42{,}000+820\ C+1000\ P+y\ Mn+R=\text{Ultimate strength.}$$

I am indebted to my brother, J. W. Campbell, of the Pennsylvania Steel Company, for collecting the data and assisting in the arithmetical work involved in this paper.

DISCUSSION.

Mr. **William R. Webster** (Philadelphia) said: We are under great obligation to Mr. Campbell for his exhaustive investigation, and the results he has put before us to-day. They are the most complete series of tests that have ever been made, where all the conditions of rolling, &c., were kept uniform. In discussing Mr. Campbell's first investigations, I claimed first, that the method of least squares, then used, would of necessity only give the average value of any element, and that if the effect of any element was greater in the presence of high carbon than with low carbon this would not be shown by the method of least squares. Secondly, that the effect of manganese should be considered on acid steel as well as on basic steel, instead of ignoring all the effect of that element when it was below 0·60 per cent., as was then recommended by Mr. Campbell. I am pleased to note that the results of his present investigation confirm my views on these points. In presenting the results of his first investigation, Mr. Campbell referred to my investigation of 1893–94, and took exception to the value of phosphorus varying (depending on the amount of carbon present) from 800 lbs. to 1500 lbs. for each 0·01 per cent. He claimed that one might just as well consider the effect of phosphorus as being constant, and of carbon varying. I refer to this, as he now has introduced very similar conditions in his present tables, in that he gives variable values for manganese (depending on the amount of carbon present) for both acid and basic steels. Can we now say, with more certainty than formerly, which element should be considered as having a constant effect? There is one other point that I took up in my former discussions, it is the matter of grouping the tests together, and getting an average of each element in the steels of the group—and from these average results working out the values. I worked with the individual tests and analyses, and consider them much better. I trust Mr. Campbell will give us the full results for each individual test, in order that others may be able to work out the values for each element by their methods. This, no doubt, would result in bringing into line the views of the different investigators on this important subject. For instance, would not the individual tests and analyses assist in deciding whether phosphorus should vary from one to one and seven-eighths times the effect of carbon, as I have it in my paper before this Institute in 1894? Or should the effect of phosphorus be constant and that of manganese vary in accordance with the amount of carbon present, as Mr. Campbell has it in his present paper? But, of course, it is much better to keep the effect of carbon per unit constant under all conditions, if possible, as that is the element we depend on the most. Mr. Campbell's present investigation will greatly assist in harmonising the work of others, as they have all worked with the method of "successive approximations," that is, "cutting and trying," and it will now be a very simple matter to compare results. In my own case I have no disposition to insist on the former value given for each element, which though based upon numerous careful observations, and proved by many subsequent tests to be approximately reliable in practice, are still open for correction, and will be unhesitatingly withdrawn whenever any other shall be shown to fit the observed facts more closely. The practical value of the estimated ultimate strengths is now recognised by the steel manufacturers, and they use them in their everyday work. The colour carbon determinations are used on account of the quickness of the method. I have not had time to study Mr. Campbell's paper as it deserves, but I have attempted to put his results in convenient form for comparison with those of Mr. Cunningham and my own. A table prepared in 1902 gives the values for each 0·01 per cent. phosphorus up to 0·08 per cent., in connection with each five points of carbon from 0·06 per cent. to 0·60 per cent., and each five points of manganese from 0·20 per cent. to 0·60 per cent. Using Mr. Campbell's new values for carbon, phosphorus, and manganese for acid and basic steels, and the carbon by both colour and combustion, a new table was prepared, and a comparison of the results shows that, notwithstanding the differences of the values of each element used by the different investigators, the estimated ultimate strength by the different methods agree much more closely than we would expect. It would therefore seem to me that this matter will yet be very much simplified. For instance, have we enough data before us to say that the same amount of carbon in acid steel has from 30 per cent. to 40 per cent. greater effect than in basic steel? In the present case this greater value for carbon in acid steel is compensated for by giving the manganese a much greater value in basic steel, and also by using a higher value for pure iron in basic steel than in acid steel. The factor "R," given in all equations as a variable to allow for heat treatment, is of the most importance, as it has considerable effect on the physical properties of the steel. Formerly it was much neglected, but since the mills have been grading the steel by the estimated ultimate strengths, the heat treatment in rolling has been much more closely watched. In 1894 I made a strong plea for an investigation to be made on the heat treatment of steel in connection with the work of rolling and forging. A great deal has been done in this line since then, but there is much still to be done. I agree with Mr. Campbell in that it is not necessary to take the microstructure of the steel into consideration from the standpoint of his investigation. Yet anything that will in any way assist in controlling the heat treatment of the steel should be looked into. In the ordinary microscopical work they have not tied up the fractures of a nickel and broken piece of steel, as we know it with the microstructure of the same steel. This step from the old to the new has long been needed, and I now desire to call attention to a method of slight etching and low magnification with a hand-glass that is very promising. It looks as though by this method we will be able to tie up the fractures of steel of, say, 0·50 carbon and under. These pieces are from the same bar of 0·35 carbon acid open-hearth steel. One piece was overheated and shows the large coarse structure; the other piece was overheated and then annealed: it shows a much finer structure. A test of this kind would be useful in the case of large driving axles, as a small spot could be polished and etched; the glass would show if the steel had been finished at too high a temperature in forging; that is, if it had too large a grain and in a dangerous condition. This method of investigation is offered at this time as a suggestion, in the hopes that others will take it up and improve on it.

Dr. Charles B. Dudley (Altoona, Pa.) said: I would like to say, with regard to Mr. Campbell's paper, that it has been known for years, I think, that there is a relation between the chemistry and the physical properties of a piece of steel. In the course of our work in connection with the Pennsylvania Railroad, we not infrequently have to examine broken parts. We do so by making both physical test and chemical analysis, and for a long time we have been impressed with a close relation between the chemical analysis and the physical properties. We ourselves, however, have never made any attempt to put this relation into figures. We can but admire the enormous amount of work that has been put upon this subject by Mr. Webster and Mr. Cunningham, and last and perhaps best of all by Mr. Campbell.

There is one phase of the question which Mr. Campbell does not claim for his work, and which we find very useful, namely, at times it is not possible to get enough of a broken part to make a tensile test. In that case we make an analysis, and interpret that analysis into a tensile test. We are constantly doing this, and are willing to say that the information so obtained is of very great value. Furthermore, as is well known, most of the specifications of the Pennsylvania Railroad are both physical and chemical, and in making those specifications it is necessary that the chemistry and physical properties should agree, and here again is another place where we use the figures obtained by Mr. Campbell. To my mind his work is worthy of all praise.

Mr. Robert W. Hunt (Chicago) said: It gives me great pleasure to add my tribute in praise of Mr. Campbell's work. In the old days I do not know that I should have been so glad to have had the definite formula for steel presented, with the definite order as to exactly how the process of manufacture should proceed, the chemistry prescribed, and certain physical results demanded. But now that I am on the other side of the House, I think it well that these prescriptions should be made. The great point is that they should be intelligently given out; that is, based upon such information as to-day intelligent research presents to you. We all, who have been connected with the steel industry for many years, know that for a long time steel was regarded as a sort of unknown problem, and a hopeless one, so that its idiosyncrasies should be accepted with regret, but still accepted. But that time is passing away. Now we can pretty nearly always tell why those peculiarities occur.

I have no doubt as the investigations proceed the time will happily come when we can always tell. Dr. Dudley has done more than any other expert in this country to draw correct deductions from the points that he mentioned to-day; that is, from the failures. In some of the discussions of the American Society of Civil Engineers the value of the scrap-pile has been enlarged upon; notably by one of its past-presidents; and that scrap-pile is a lexicon from which all manufacturers of steel can derive valuable knowledge.

Dr. J. A. **Mathews** (Syracuse) said that his experience had been entirely in other grades of steel than those which Mr. Campbell had brought forward, so he did not think he could add anything of value. The relation between the manganese and the sulphur might be considered specially, inasmuch as it was generally considered that the manganese and the sulphur combined chemically so far as there was an excess of manganese, and then the free manganese uncombined might exert an effect independent of the total manganese. That was merely one phase that occurred to him as being worthy of looking into. He was sorry that his experience had not taken him into this field. He appreciated very greatly what Mr. Campbell had done, and thought it would be of immense value to the industry upon the structure of that grade of steel which is so important.

Mr. **Campbell**, in reply, said: Mr. Webster raised the question whether the lower value for carbon in basic steel was not due to the higher value of the base. A little calculation would show that this criticism applied only to a limited range of low carbon steels. The value of carbon in acid steel was 1000 and for basic steel 770 pounds. In a steel of 0·30 per cent. carbon the effect of carbon in the one case would be 30,000 pounds and in the second 23,100, a difference of nearly 7000 pounds, while the base for basic steel is only 1500 pounds higher than for acid metal. It is quite evident that no change in the value of the base can make up for an actual difference in the effect of carbon. A base can arbitrarily be assumed, and a value found for carbon for low steels, or another can be assumed and another value found for high steels, but if a formula is to fit both high and low steels, the base can not be assumed, but must be worked out from the records. It was also suggested that a list of the individual heats should be printed, but it seemed unnecessary to burden the pages of the Journal with the chemical and physical records of 1800 heats. The full record, however, would be given to Mr. Webster for his investigations.

A cordial vote of thanks to Mr. Campbell was passed unanimously, and the following paper was read:—

MINING AND METALLURGY AT THE ST. LOUIS EXPOSITION.

By H. BAUERMAN, F.G.S., Assoc.M.Inst.C.E. (Honorary Member).

THE exposition commemorative of the centennial anniversary of the purchase of the Louisiana territory differs in many ways from its predecessors in the United States. Notable among these differences is the very large scale upon which ground and buildings have been planned, the former extending to 1263 acres, with a total roofed area of buildings of 300 acres as compared with 633 and 194 acres respectively at Chicago in 1893. The system of organisation also seems to be rather towards a concentration and summarising of the exhibits into collections giving a condensed view of the resources of the different States without making the work that of an individual exhibitor, and this is characteristic alike of the European as well as the American State displays. In fact, as far as the subjects likely to be of most interest to the members of the Institute, it may be considered as essentially a show of first materials; coal, refractory materials, and, to some extent, iron ores being well represented, while the subjects of iron and steel manufactures have attracted but few contributions. To some extent this may be due to the practical extinction of iron-ore smelting in the State of Missouri, owing to the exhaustion of the classic iron-mines at Pilot Knob and Iron Mountain, about 90 miles south of St. Louis, which at their period of best yield supported 18 blast-furnaces, which have since been partly dismantled, only a single charcoal furnace remaining in blast. There is, however, a considerable steel foundry interest, the works being favourably situated for the supply of scrap from the numerous machine works, but the competition of the red ores of Lake Superior and the cheap phosphoric irons of the south have effectually destroyed the value of the lean ores of Southern and Central Missouri as sources of pig iron supplies. As against this falling off, however, there has been a very large development of both zinc- and lead-smelting in Missouri, Kansas, and other neighbouring

States, which industries centre largely in St. Louis; and these and the allied fire-clay industry are very much in evidence in the show. Having regard to the many and varied attractions presented by the Mines Building, it has been thought desirable in the interest of the visiting members not to restrict the following paper to iron and steel alone, but to indicate in addition some of the more prominent objects of interest lying outside the main subject.

IRON AND STEEL.

The Palace of Mines and Metallurgy * occupies the south-eastern corner of the fan-like group of buildings forming the central features of the exhibition. It is rectangular in form, measuring 750 feet in length (SE.–NW.) and 525 feet in breadth (SW.–NE.), covering about 9 acres. The enclosed area, which is entirely on one level without galleries, is divided by eight longitudinal and six transverse passages into a system of rectangular blocks numbered in order from 1 to 83, the index number being displayed above the centre of each block for the convenience of reference. Somewhat less than half the space is occupied by foreign contributions, which are mainly grouped in the NE. and NW. quadrants, the larger portion being allotted to the systematic collections of the different States and those of individual exhibitors. The latter, which are perhaps of the most general interest, will be mostly found in the transverse line of the centre of the building, the actual geometrical centre being marked by a lean-to arch formed of rails varying from 8 to 100 lb. to the yard from the Carnegie Steel Company. Immediately within the principal east door we find the important exhibit of the Bethlehem Steel Company, which is the largest single contribution in the building and occupies a space of 150 by 65 feet. This is sunk about 6 feet below the level of the main floor to allow the necessary space overhead for a full-size working model of a naval turret with two 12-inch guns. Other ordnance from 5-inch calibre downwards are exhibited in actual examples, and a new continuous breech action for an 18-inch gun, in which the

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* In addition to the main building, there are collections in the metal pavilion and several full-sized working-exhibits in the "Gulch" lying to the SW. of the main building.

whole of the movements involved in the opening and closing of the breech are effected by five turns of a crank-handle. The larger objects include a Whitworth fluid-compressed ingot weighing 40 tons, a hollow forged jacket-tube for a 13-inch gun weighing 20 tons, a tube of a 5-inch gun machine for assembly, a hollow forged shaft for 5000 horse-power electric generator, 20 feet 2 inches long, weighing 10 tons. Armour plates, from 4 to 11½ inches thick, are represented by specimens that have been tested on the firing-ground; but the heaviest plate for the United States battleship *Louisiana*, together with the ingot from which it was produced, are given as models, the weight of the latter being 61 tons, and of the former, which measures 198 by 11 inches with a tapered thickness of 9 to 4 inches, 56 tons. In connection with these, a curious object-lesson has been arranged on three sides of the enclosing walls, representing the materials consumed in the making of the steel plates and the quantities of fuel required both for heating and power purposes in the different operations of pig-iron melting, open-hearth steel making, and the various stages of heat-treatment, machining, carburising, straightening, bending, hardening, &c., which go to make up the finished plate, the quantities being given for each model, which is ⅕ of the entire dimensions or $\frac{1}{125}$ of the volume of the full-size plate. Altogether, some twenty-six operations are involved, each calling for the consumption of a considerable pile of fuel, which is represented in the reduced scale. The effect, however, is somewhat lessened by the omission to give the weights of the different piles, but the enormous fuel-consuming character of the operations is sufficiently apparent. A section of three rings of the cast iron linings used in the tunnels under the Hudson and East rivers in the Pennsylvania Railroad Company's new lines in New York and Brooklyn is also shown. In connection with these it may be mentioned that fully detailed models of these works will be found in the Pennsylvania Railroad's exhibit in the Transportation Building.

Adjoining the Bethlehem exhibit (Block 21) is a very fine display of rolled plates and flanged and dished work of all kinds in iron and steel by Messrs. Worth Brothers Co., of Coatesville, Pa., the principal feature being a boiler plate 0·72 inch thick, 46 feet 2 inches long, and 11 feet 10 inches wide, weighing 7 tons 14 cwt. This was rolled on a three-high mill with rolls 12 feet 5 inches long, and is stated to be the largest boiler plate ever made. Another smaller plate 0·5 inch thick, weighing 2 tons, is 12 feet 2 inches wide, or within 3 inches of the effective aperture of the mill on either side. There is also a considerable display of locomotive boiler-tubes, made from wrought-iron blooms produced in a charcoal knobbling fire.

Another display of flanged and pressed steel work is presented by the Glasgow Iron Company of Pottstown, Pa. (Block 63). This includes various examples of flanged and dished heads, pressed steel manholes, with lugs for boilers, punched plates for bridges, and similar work. Welded work in steel is represented in the contribution of The Continental Iron Works of Brooklyn, which, however, is not in the Mines Building, but some distance away in the Machinery Building, who send a series of corrugated marine boiler-furnace flues and fronts, both on the Morrison and Fox systems, and a large boiler for disintegrating wood-pulp with caustic soda in cellulose-making. This is made of ¾-inch steel plate 42 feet 9 inches long, and 9 feet internal diameter, for a working pressure of 125 lb. to the square inch. Malleable iron of special toughness for boiler stay-bolts is shown by the Ewald Iron Company of St. Louis (Block 73). The material appears to be open-fire charcoal iron.

Continuous billet-, rod- and wire-rolling forms the principal subject of the exhibit of the Morgan Construction Company of Worcester, Mass. (Block 2), which adjoins the central door on the north-east side. This includes a full-size example (part in section) of the Morgan Gas-Producer, and has sectional full-sized models of parts of heating furnaces for billet and rod working continuously, one having a system of water-cooled skid bearings for the billets, while the other is the suspended roof Morgan heating-furnace with continuous tubular heat recuperator for warming the air supplied by a fan-blower at the upper end, and the gas-producer at the opposite end of the inclined bed, whose construction will be familiar to many of the members, as it was prominently brought forward in a paper by the late Mr. William Garrett, at the Institute meeting of 1901, in London. The gas-producer is of the tub- or kiln-shaped form, standing above a water-sealed ash-pit, with a conical blast-pipe delivering air by a steam-blower into the centre of the fuel. The feed arrangement is George's development of the Bildt spiral distributor, the distributing-plate being fixed while the closed coal-hopper revolves around it by a system of toothed-gearing, driven from the shaft of an independent motor. These producers are made 8 and 10 feet in diameter, corresponding to a gasifying power of an equal number of tons in 24 hours, about 88 per cent. of the thermal value of the fuel being delivered in the gas. The rolling-mills include a rod-mill of 6 stands of two-high rolls, and a wire-mill of 8 stands, also two-high, arranged in continuous series. With a mill of this class, rolling 1½-inch billets, sheared by flying shears, also exhibited, into 30 feet lengths, there were produced from a single bloom :—

	lb.
30 billets together weighing	6750
1 crop end	6½
1 short length	22½
	6779

This exhibit is among the most noteworthy contributions to the Mines Building, and it has been worked out in such a manner as to merit a careful examination from those interested in the subject. Heavy machinery for rolling-mills and forges is unrepresented by any actual examples, but there are some remarkably fine series of photographs of such machinery contributed by Mr. Julian Kennedy and the Mesta Iron Company, both of Pittsburg, which will be found on the outer wall of the court occupied by the American Institute of Mining Engineers, and the United States Geological Survey, on Block 74.

The American blast-furnace has been brought so prominently before the world in the proceedings of the professional societies of both sides of the Atlantic, as well as in the technical press, that it may have been supposed to be insufficiently attractive for exhibition purposes. Such a supposition is required in order to account for the practical absence of any illustrations of this important subject. The Lawrenceville Bronze Company of Pittsburg, Block 63, shows full-size examples of 6- and 8-inch water tuyeres, as well as a jumbo or cinder-notch cooler in bronze and copper. They have also sent some examples of babbited bronze-bearings for the necks of heavy rolling-mills, in which the soft metal is arranged in lines diagonal to the axis of the roll.

Another full-size blast-furnace accessory is the cinder-car shown by Mr. E. A. Weimer, of Lebanon, Pa. (Block 72). This is mounted in trunnions parallel to the axis of the railway and tipped sideways by trunnion-rings, geared on fixed racks on the frame of the truck, the action being the reverse of that of the Bessemer converter. The rotation is effected by a steam-engine which is supplied from the boiler of the locomotive by a flexible pipe. The opposite trunnion is connected with an hydraulic cylinder safety-brake, which prevents the slag vessel from exceeding a safe rate of speed in turning. The car is of 200 square feet capacity, 9 feet in diameter at the top, 5½ feet at the bottom, and 6½ feet deep. The total weight is about 60 tons.

A new charcoal blast-furnace plant containing some interesting novel features is represented by a small model, contributed by the Cleveland Cliff Iron Company and the Pioneer Iron Company of Cleveland, Ohio. It is in the Michigan court, Block 31. The furnace at Marquette, Michigan, 70 feet high and 12 feet wide in the boshes, makes 130 tons per day of Bessemer iron from the ores of the Lake and Cliff shaft mines of the first-named company, the yield being 52 per cent. with a charcoal consumption equivalent to about 15·2 cwts. per ton. Only about 1 cwt. of limestone is used, and the cinder is something less than 4 cwts. per ton. The blast at 8 lb. pressure is heated to 1250° Fahrenheit in three 70-feet by 16-feet Cowper-Roberts stoves. The charcoal is made in kilns adjacent to the furnace from hard wood brought from a distance by railway, the company owning and controlling about 2200 square miles of woodland. The kilns, 86 in number, somewhat resemble bee-hive coke-ovens, have a capacity of 80 cords, or about 160 tons of wood each, four ovens being drawn for each day's work of the furnace. When charged and fired from the top, the first smoke and vapour is allowed to escape by the chimney until the bulk of the contained water is driven off, after which the chimney connection is closed, and the gases are drawn by a fan through copper surface-condensers, which give the so-called green liquor, a mixture of water with tar, acetic acid, ammonia, and other compounds, of which alcohol, acetic acid, and formaldehyde are recovered commercially. The incondensable gases pass to the boilers as fuel, and the tar, removed from the acid water by settling in tanks, is similarly employed, being sprayed into the fires by steam injectors. These, together with the furnace gas in excess of the quantity taken by the stoves, are, however, insufficient to supply the whole of the steam required, and 8 out of the 12 Sterling water-tube boilers, aggregating 3600 horse-power, are equipped with Murphy automatic stokers for bituminous coal, and the charcoal breeze is disposed of by mixing it with the coal in the feeding-hoppers.

The liquor, after the removal of the tar, is subjected to a progressive series of distillations; the first product, containing alcohol and acetic acid, is carefully neutralised with milk of lime, producing acetate of lime. Subsequently, by repeated rectification, methyl alcohol of 95 per cent., colourless and free from objectionable odour, is obtained. A large number of photographs are given in addition to the model illustrating the method of handling the wood, from the cutting in the forest to the charging in the kilns, and a graphic illustration shows the products obtained in carbonising. This starts with a maple log 12 inches in diameter and 10 feet long, representing $\frac{1}{16}$ of a cord of wood, or about 2½ cwts., which produces about ½ cwt. of charcoal (or about 20 per cent. yield), together with 13 gallons of pyroligneous acid, ½ gallon of wood tar, 4 lbs. of grey acetate of lime, and ¼ gallon of 95 per cent. refined wood alcohol. In 1903 the make was 444,423 gallons of wood alcohol and 3000 (short) tons of grey acetate of lime. The metal made ranges from 2·75 to 0·10 in silicon, 0·15 to 22 in phosphorus, 0·00 to 0·018 in sulphur, being essentially foundry iron of the highest class.

Messrs. Rogers, Brown & Co., of New York, show a large series of fractures of American foundry irons, similar in character to their contributions in former exhibitions. The districts represented are Virginia, Tennessee, Georgia, and Texas for the South, and Lake Superior, New York, and Ohio for the North. The samples from one of the Ohio works, the "Star" brand, are noticeable for their high proportion of silicon.

Mr. A. E. Barber, of Newark, N. J. (Block 73 G.), illustrates the manufacture of malleable castings with two full-size sectional models of an air-melting furnace, and an annealing furnace, charged with the pots containing the articles to be tempered, in addition to numerous examples of finished work. This business was started by Seth Boyden, who originated the process in America in 1826, and has since been continuously carried on in the same place by a collection of firms representing his descendants, down to the present time.

The largest mass of cast iron in the Exhibition is the great iron man in the centre of the Alabama court, close to the middle door of the building on the north-west side, which is intended to show forth the colossal iron-deposits of the State. According to the description, it represents primitive man at the time he discovered how to harden iron and steel, and Vulcan holding aloft the finished spear-head as a result of his knowledge and handicraft, a somewhat obscure proposition. What is certain, however, is that the figure is 56 feet high, and weighs about 53 tons. It seems to be well adapted for its present purpose. Chilled cast-iron wheels, which have usually been prominent in American exhibitions, are on the present occasion entirely unrepresented in the Mines Building, as are also crucible and other kinds of high-carbon steel; but there is an important exhibit of chilled wheels in the Transportation Building by the American Car and Foundry Company of St. Louis, which has an output of over 800,000 wheels per annum averaging about 5 cwt. each. Nickel-steel of the 3½ per cent. nickel class forms a principal feature in the collection of the International Nickel Company of New York, Block 42. This contains examples of the ores in current use, both from Canada and New Caledonia, intermediate products at different stages of reduction, and metallic nickel as prepared for different uses, and the accessory metals recovered in the reduction process, copper and a weak proportion of gold, silver, and metals of the platinum group, which are contained in the ore of the Sudbury district in minute proportions. As examples of the wearing properties of nickel-steel, parts of heavy rolling-mills, including rolls, pinions, coupling-boxes and spindles, are shown as taken from use after rolling different quantities of blooms and sections varying from 22,000 to 300,000 tons. There are also examples of the nickel-steel rails made by the Carnegie Steel Company for the Pennsylvania Railway Company, for use on the Horse-Shoe curve of the main line near Altoona, where the life of carbon-steel rails is measured by months only. From the roof is suspended a model of a casting in 6 per cent. nickel steel for a 10,000-ton forging-press cylinder. The original weighs 330,000 lb. (147½ tons), and is stated to be the heaviest casting of this material made up to the present. Tires, wheel-centres, piston-rods, and other parts of locomotives are also made of the 3½ per cent. alloy. As an example of the toughness, a finished piston-rod has been tied cold into a knot. The higher alloys of nickel have not received much attention in America, the tendency being rather in endeavouring to introduce the pure metal in boilers and other places where the metal is subjected to corrosive action. As an example, a set of full-size locomotive boiler-tubes has been made in pure nickel, but as yet they have not been tried in practice. Probably the cost is somewhat deterrent. An interesting accessory feature of this very fine exhibit is the Wharton historical collection contained in two table-cases, which exhibit the work done by Dr. Joseph Wharton, resulting in the production of pure malleable nickel in 1865.

Manganese steel is a principal feature in the large display of crushing, grinding, and screening machinery for mining purposes, made by the Taylor Iron and Steel Company of High Bridge, N. J. (Block 73). The most important example in this collection is a drum-screen 30 feet long and 5 feet diameter, in which the perforated plates are cast to pattern, and all wearing parts are made of the same metal. The difficulty of fitting in this, as in other examples, is got over by coring the castings with soft steel, in which any subsequent machining is done by boring and turning in the usual way. The wheels for the charging-barrows for blast-furnaces, made of the same material, are remarkable for their comparative lightness. The whole collection is one that merits very careful inspection from all who may be able to get the time to do so. Manganese-steel in the form of the crushing-mantle in a Gates crusher also appears in the large collection of crushing and dressing machinery exhibited by the

Allis Chalmers Company, which occupies a large space, and epitomises the whole range of machinery used in the reduction of gold and silver ores, as well as the process of pan-amalgamation. A better idea can be got of the ore-milling machines of the West by a short view of this collection than by the perusal of pages of printed matter. Another peculiarly appropriate application is seen in the large exhibit of manganese-steel safes adjoining the Tiffany gem exhibits on Block 40.

IRON ORE.

The iron ores of the United States are very fully represented in the different State collections, but mostly in such a manner as not to be easily identified by the casual observer, as they are in great part used either in decorative objects heaped up in piles to accentuate the features of more attractive exhibits, or else incorporated in the metallurgical collections of the museums of the States, or Schools of Mines, where their individuality is mainly lost. There is one notable exception, however, in the model of the Fayal mine at Eveleth, Minn., which holds the distinction of being the largest producer in the world, the output for the last year having been 2,000,000 of short tons. This is in a kind of basin-deposit of the soft red Mesabi ore which has been worked by stripping the surface-drift and excavating the ore with a steam-shovel as long as the gradient admitted, but now the system of milling is used in which the ore is passed from the surface—working by short shafts to a level below and raised through a main shaft. The methods of working are similar to those described in the paper of the late Mr. Jeremiah Head, read before the Institution of Civil Engineers. There is a very fine collection of Minnesota ores in the State collection, contained in large glass bottles, with the details of composition attached to each, but these, as previously stated, do not attract the casual observer. The Michigan ores, in the same way, are represented in the collection of the Michigan School of Mines at Houghton, who do the same good office for the copper-mines of Keweenaw Point. The central feature in the Minnesota collection is, however, the large pictorial model of the harbour of Duluth, showing the arrangements for handling iron ore and other bulk cargoes with the extreme rapidity rendered necessary by the short summer navigation season on the Great Lakes.

The soft red oolitic ore of the Southern States, the great feature in the iron-making resources of America, is very much in evidence in the minerals piled up at the feet of the iron man of Alabama, and the extension of the same class of deposits is evidenced in the collections of the adjacent Southern States. Of the older mines, the Cornwall Ore Banks in Pennsylvania, though proportionately of less importance than formerly, still maintain a high production. The total output of these deposits of rich magnetite—low in phosphorus, but containing sulphur and copper in rather considerable proportion—since 1740 has amounted to 16,300,000 short tons, the quantity for the period, 1892–1903, being 4,782,000 tons. Judging from the accompanying photographs, the picturesque character of these ore-banks, which will be remembered by those who visited the mines in 1890, has in great part disappeared, under the levelling influence of steam-shovel mining. Among new and undeveloped deposits, the red hæmatite of Sunrise in Wyoming, and the dense red and magnetic ores of Utah are noticeable; the exposures of the latter are stated to amount to 500,000,000 tons of from 64 to 68 per cent. ore. The Sunrise ore, containing 60 to 68 per cent. of iron, and practically free from phosphorus, is the main source of supply of the Colorado Fuel and Iron Works at South Pueblo. The mining has been done by steam-shovel, handling about 2000 tons of material per day, but works are in progress for developing the ore in depth from a new shaft, to do away with the open-pit method.

The older magnetic ores of the Adirondack region are mainly represented by cabinet specimens in the New York collection, but the application of the Wetherill magnetic separator to ores of this class, containing apatite and silicates, is shown by Messrs. Witherbee, Sherman & Co., in the New York court. The Maryland court contains some examples of cast iron projectiles and small rolls made from iron smelted at the Muirkirk furnace, which dates back for about a century and a half. These are interesting as being smelted from nodular-carbonate ores of

Cretaceous age, which give a metal similar to the "best mine" iron of Staffordshire smelted from similar ores.

In the enclosed court, Block 74, occupied by the United States Geological Survey and the American Institute of Mining Engineers, Professor C. R. Van Hise has epitomised the information obtained during the detailed survey of the principal American mining regions. This is given in a series of charts or diagrams, with specimens attached, showing the changes in the minerals. The Lake Superior ores are considered as having originated in deposits of siliceous and, to some extent, pyritic spathic ores in the Archean and earlier Huronian formations, which by partial oxidation and transformation have in one direction resulted in the production of hornblendic rocks containing magnetite, while in another complete oxidation, and the more or less complete removal of silica, have given the whole range of red ores from the soft Mesabi to the denser slate irons of the Marquette region. Where the silica has been less perfectly removed, the curious mixture of red jasper and hæmatite, known as Jaspilite, has been largely formed; and from the alteration of this some curious beds of brown hæmatite at the base of the Cambrian series have resulted. Similar charts are given for the origin of the gold, silver, and copper deposits of the Rocky Mountain regions, the Lake Superior copper deposits, and the zinc and lead ores of Missouri, all of which are deserving of careful inspection, as presenting a difficult subject in a new and popular manner, without sacrificing accuracy in detail.

COAL.

The city of St. Louis is in the fortunate position of possessing one of the cheapest coal supplies in the world. This is due to the immediate vicinity of the Illinois coal-field, whose western outcrop follows the line of cliffs on the left bank of the Missouri, exhibiting a regularly stratified 7-foot seam of coal which can be easily and cheaply mined. This seam is worked in about fifty mines within a radius of about sixty miles, at depths rarely exceeding 600 feet. The capacity of the mines ranges from 200 to 2500 tons daily, the price varying from 45 to 75 cents. per ton on cars at East St. Louis. The equipment of the mines is mostly of a simple character, pillar and stall working with machine coal-cutters being generally used. Good evidence of this wealth of coal is afforded by the Illinois State collection, which contains full-size sections of all the principal seams, the largest being a block measuring 6 by 7 by 8¾ feet, the latter dimension giving the thickness of the seam, which weighs 14 short tons, and numerous other sections from the Madison Coal Company's No. 6 pit at Divernon, Illinois, and is said to be the largest single mass ever raised. Other columns of smaller dimensions accompany it. The most prominent coal exhibits, however, are to be found near the centre of the building, the largest being that prepared jointly by the Fairmount, Somerset, and Consolidated Coal Companies. The principal feature is a model on the scale of an inch to a foot of the underground workings and surface arrangement of a bituminous coal-pit worked from a level, with the pit-village, and the screening and loading arrangements for saleable coal, known under the comprehensive term of "tipple," the slack elevators and charging arrangements for a bank of beehive coke-ovens. The sections of the model are so arranged as to show the method of underground haulage by compressed air locomotives, giving a very popular if somewhat simplified idea of the conditions of actual working. Another large concern, the Pittsburg Coal Company, which has an output of 15,000,000 tons per annum, shows in a somewhat similar model the pillar and stall method of working in various stages of development, the undercutting being done by machine coal-cutters. Another model shows the staith and shoot in loading coal steamers on Lake Erie. In addition to the model, much interesting information concerning the distributing operations of this company is to be found in the excellent descriptive pamphlet accompanying it.

West Virginia, whose characteristic product is smokeless steam-coal, like that of South Wales, shows two good topographical models of the Great Kanawha and New River coalfields, a section of the Pocahontas steam-coal seam, and a model of the surface arrangements of the Davis and Hardy Colliery, with a very effective sectional background, representing the beautiful scenery of the Appalachian mountain region.

The working of anthracite is illustrated by a generalised model in the Pennsylvania State collection, in which every class of mining, from the ordinary single stall worked in flat seams to the method by stoping and filling where the seams are nearly vertical, together with the method of stripping and open-pit work in the districts where the Mammoth seam comes to the surface. Accompanying this is a large working-model of an anthracite breaker, and a large amount of valuable information on the geological relations is supplied in models and maps by the State Geological Survey. Another model of a bituminous coal "tipple" gives the surface arrangements, pit-frame, and winding-engines of a deep mine, with a more elaborate equipment than those of the mines previously noticed. The best model, as representing actual working conditions of a large mine, is that of the Jenny Lind mine in Arkansas, belonging to the Western Coal Mining Company of St. Louis. This represents the working of a thin seam by a system of broad panels or chambers, with narrow intermediate pillars, and is the nearest approximation to a long wall method exhibited.

The most interesting feature in connection with coal in the Exhibition is, however, to be found in the Fuel-Testing Plant of the United States Geological Survey, which has been established by the department in Washington, with the co-operation of a very large number of machine-making and other firms, who have lent the necessary plant for the investigation. The object is to test on a working scale the evaporative and other values of any coal, or other fuel, that may be sent in for investigation. The plant, which is situated in the outside mining exhibition in the gulch, includes three steam-boilers, a 350 horse-power Allis Chalmers engine, driving a 250 kilowatt direct current generator, a 275 horse-power Westinghouse gas-engine with a smaller dynamo. A coal-washing plant, a rotary dryer for lignites and other wet fuel, two briquetting-machines for large and small size briquettes respectively, and three small beehive coke-ovens. For the gas-engine, a large gas-producer with scrubber and gas-holder has been provided by Messrs. R. D. Wood & Co., of Philadelphia. For the chemical investigation, a complete laboratory has been provided in the Metal Pavilion, equipped with all the material necessary for proximate and complete analyses, and calorimetric determinations by the Mahler bomb calorimeter. This plant, however, is not a mere temporary exhibition attraction, but is of a more permanent character, and will probably remain in use for a considerable time, as there is a prospect of the investigations being carried out on a very extensive scale.

COKE.

Coke is largely exhibited from the principal coke-making centres, both in Pennsylvania and Western Virginia, in the long prismatic pieces and silvery semi-metallic lustre characteristic of the beehive oven. The only contribution dealing with by-product oven practice is made by the Semet Solvay Company, the United Coke and Gas Company, the American Coal Products Company, and the Barrett Manufacturing Company. This comprises a full series of coal-tar and other products condensed from coke-oven gases, examples of their use for roofing, agricultural, and other purposes, and some remarkably fine sectional perspective drawings of Otto Hoffmann and Semet Solvay coke-ovens, as modified for American use, and of the condensing plant of the Lackawanna Steel Company's coking works at Buffalo, dealing with 33,000,000 cubic feet daily. The principal novelties in the ovens are the adoption of a chain-bucket elevator in conjunction with a travelling hopper-box for filling, and the suppression of the cooling-banks, the finished charge being either pushed into a closely-fitting metal receptacle, where it is cooled out of contact * with the air, or allowed to fall into a hopper-shaped car subjected to a heavy flood of water, which drains off through the bottom of the car, leaving the coke in a condition for loading.

REFRACTORY MATERIALS.

Fire-bricks and other refractory clay wares are very fully represented in the collections representing the Clay Industries of the United States, which are grouped together in the south-east corner of the building. This includes a large and varied series of objects from ordinary building brick to the higher

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* This method was noticed by Mr. B. H. Thwaite in the discussion on Mr. C. Lowthian Bell's paper in May 1904. *Journal of the Iron and Steel Institute*, 1904, No. I. p. 216.

qualities of pressed and enamelled bricks, and terra-cotta and even pottery, the line between ordinary clays and ceramic wares not being very precisely defined. In most of the large American cities, the tendency to the use of moulded clay, instead of stone, seems to be on the increase, and the change is no doubt favoured by the large use of skeleton-iron framings, in place of solid walls where the fillings have to be as light as possible. According to Mr. H. A. Wheeler, the annual value of the clay produced by the United States, 122,000,000 dollars, is even greater than that of the gold and silver output collectively. The St. Louis district is an important centre for fire-brick manufacture, the basis of the industry being a grey plastic clay occurring at the bottom of the coal measures which occur over an area of about 170 square miles. This when burnt combines refractory character with great strength and resistance to abrasion, and it is well suited for making glass pots and gas and zinc retorts. When burnt it takes a reddish-brown tint variegated with black spots due to the fluxing of interposed grains of pyrite in the same manner as the Glenboig brick, which it closely resembles in essential characters. A more refractory material is the so-called flint fireclay, which is essentially a compact, non-plastic, china clay, which occurs at distances of from 40 to 140 miles west of St. Louis in irregular deposits or pockets in Carboniferous or Silurian limestone. These represent old pot-holes whose filling probably dates back to Cretaceous times. The composition is that of a nearly pure kaolinite, or china clay, but with a slight excess of alumina over Cornish clay, and a total of fluxing impurities varying from 1 to 2·8 per cent., or averaging 1·8 per cent. This is extremely refractory, but not being plastic, it can only be moulded by mixing it with a proportion of the grey clay.

Examples of the application of these materials to the manufacture of retorts and other moulded work are afforded among others by the Missouri Fire Brick Company, the Mississippi Glass Company, and the Laclede Fire Brick Company, the latter firm having a larger exhibit in the gas-works section of the Manufactures Building, where some bricks for basic furnaces are shown containing 70 per cent. of alumina. These are obtained by adding bauxite to the natural refractory clay mixtures.

OTHER EXHIBITS.

The zinc and lead industries of Missouri are based upon the occurrence of large but irregular deposits, usually of a brecciated character, filling transverse fissures, as well as spreading irregularly between the bedding-planes of the Silurian limestone, the ore-bodies being described by Mr. Bain, of the United States Geological Survey, as resembling in form large, irregular, and very knotty potatoes. The minerals are essentially blende and galena. The former, which is most abundant, is of a light yellowish-brown colour, exactly resembling that of the Minera mine, with at times a canary-yellow incrustation indicative of cadmium sulphide. It appears to be practically free from iron. The most active centre of production is Joplin, in the southwestern part of the State, the mines extending into the adjacent parts of the Indian Territory and the States of Arkansas and Kansas. The annual ore production in the district averages about 250,000 tons of blende and 30,000 tons of galena. These minerals, together with the gigantic crystals of calcite usually associated with them, are profusely represented, not only in the main Missouri collection and those of the adjoining States in the Mines Building, but also in a supplementary building in the Gulch, where a full-size crushing and separating plant is also shown in operation, though somewhat intermittently. A smaller dressing plant of very reduced dimensions, one-fifth of full size, is also shown in operation in the Main Building by the students of the Missouri School of Mines, and another, about half-size, by the Utah School of Mines.

The smelting of zinc ores in the Mississippi Valley, which work began at Lasalle, in Northern Illinois, about forty years ago, has gradually moved southward, the more northern works, and those in the suburbs of St. Louis, being now eclipsed or entirely superseded by newer large works in Kansas, the reason for the change being the saving in cost in fuel with natural gas even over Illinois coal. The largest smelting-works are those of the Lanyon Zinc Company at Iola and La Harpe in Kansas, whose exhibit adjoins that of the International Nickel Company, in the centre of the building. This consists entirely of products, spelter sheet-zinc ornamental castings, and zinc manufactures of various kinds, without indication of the methods of production, but, from an accompanying pamphlet, we gather that the process is carried on in the ordinary Belgian furnace, which contains a large number of small cylindrical retorts, with clay condensers of the usual type. The principal modification is in the system of heating, a separate gas-burner and air-supply being provided for each retort, and no regenerators are used. In addition to the local supplies of ore, the Kansas Smelting-Works are treating a largely increasing quantity of blende concentrates from Colorado, the residues being subsequently smelted with lead ore to recover the contained silver.

The Niagara Falls Board of Trade makes a very complete exhibit of the principal industries that have been developed in that locality as the result of the utilisation of the water-power of the falls. This contains, in addition to topographical models and drawings, examples of the new abrasives carborundum and siloxicon, and artificial graphite, together with full-size sections of the electric furnaces as used in the production of carborundum and graphite electrodes. An example of the latter, about 5 inches in diameter, the original material being petroleum coke, is shown by the Acheson Company. A large block of a high-silicon product, containing 97 per cent. of silicon, made by the process of Mr. F. J. Tone, is another interesting novelty. Another abrasive, with the trade name of alundum, made by the Norton Emery Wheel Company, is artificial corundum, produced by melting alumina in the electric furnace without decomposition. A large crucible filled with this material is placed in the collection of the Pike Manufacturing Company of New Hampshire, adjoining the Niagara court, who show the different processes of sawing, grinding, &c., used in the manufacture of hones, whetstones, and similar articles from the novaculite rock of Arkansas, as well as a fine collection of sharpening stones from other localities, both American and European. The Pittsburg Reduction Company is represented in the Niagara Falls exhibition as a producer of aluminium, but they have a much fuller display in the Metal Pavilion in the grounds, where the application of the metal to manufacturing and domestic purposes of all kinds is completely shown. Among these the use of aluminium cables instead of copper for main electric conductors is of particular interest.

Prominent among the central features of the Mines Building is the court fitted up by the Pittsburg Chamber of Commerce, although the interest is more of a popular than a special technical kind. The central feature is a fine topographical model of the country adjoining the confluence of the Allegheny and Monongahela rivers, including the two cities of Pittsburg and Allegheny, and the principal manufacturing centres in the district, covering an area of 177 square miles, to which the name of Greater Pittsburg has been attached. The products of the different works, iron, steel, tubes, glass tiles, electric cables, &c., are exhibited as far as possible by samples in table-cases and on the walls, which are decorated with enlarged photographs of the principal buildings and points of interest, while the external embellishment shows a series of transparent photographs of blast-furnaces, rolling-mills, and other works, the whole giving a very striking picture of one of the most active industrial centres in the world.

Among the States not prominent as producers of the minerals with which the members of the Institute are mainly concerned, mention must be made of a new method of sulphur-mining shown in the Louisiana court, which is probably the greatest novelty in the Exhibition. The deposit, a limestone containing native sulphur, occurs in the western part of the State, about 40 miles from the Texas boundary, being a continuation of the oil-bearing limestone of the Beaumont district in that State. Attempts to reach the bed by sinking a shaft, however, failed through the occurrence of a heavy quicksand a short distance below the surface. A method has been devised for raising the sulphur in a melted condition. For this purpose, a line of bore-holes from 6 to 8 inches in diameter is put down to the rock, and superheated water is forced down through an inner-tube of smaller diameter. The sulphur melted out of the rock, together with the condensed water, collect in the bottom of the hole, and are forced up to the surface by compressed air introduced through a third central pipe. The discharged material is collected in temporary reservoirs (with plank sides) from 5 to 8 feet deep, where it rapidly solidifies, the mass being broken up as in ordinary quarrying when required for shipment. The output obtained by this very simple method is extremely large, as much as 33 tons per hour having been raised from a single bore-hole. Crude oil-fuel is used for steam raising, 150 barrels being sufficient for raising 500 tons of mineral. The present yield is about 1000 tons per day, the sulphur being of the highest degree of purity. A single bore will command an area of ground about 300 feet in diameter.

The mineral contributions of the Rocky Mountains and Pacific States are principally representative of the precious metal, copper and lead industries, and as such outside of the main purpose of this notice. It would be improper, however, to pass them in silence, as they contain much of great beauty and interest. The first place among them must be assigned to the Colorado collection, which contains an accumulation of beautiful and costly objects, representing the work of several decades of exploration. Prominent among these are the fine series of specimens of wire, or spider-leg, gold in the central case, the telluride minerals from the Cripple Creek district, and the large display of carnotite, the new uranium and radium mineral. North Carolina, the home of several famous mineral localities, has an interesting display of gems and rare minerals, such as rutile, zircon, and staurolite, but a principal economic feature is monagite sand, which has become of considerable commercial importance for incandescent gas-lighting. In connection with this is shown the method of concentrating the sand by the Wetherill magnetic separator, and the Welsbach Light Company contribute a series of products illustrating the method of separating and purifying the salts of the rare earths contained in these very complex minerals. There is also a full series of products from compact pyrophyllite, or talc, showing the many different uses that have been found for this substance.

The Arizona collection contains some fragments of the Cañon Diablo meteorite, which are stated to have formed part of a mass of the original weight of 50,000 tons, and to have formed a crater on striking the ground 640 feet deep and three-quarters of a mile in diameter. There are also exceedingly fine displays of crystallised wulfenite, lead molybdate, and of the ores and products of the Copper Queen mine. Another Arizona product, the brilliantly coloured silicified tree-stems which are so much used for ornamental purposes, is very much in evidence.

In the Montana collection, gold and copper ores are very strongly represented, and a fine model of the Butte district is contributed by the United States Geological Survey. There are also interesting models of workings of the Parrot, Colusa, and other notable mines, showing the underground developments by means of equidistant parallel projections on glass plates, both vertical and horizontal. These are the work of the students of the State School of Mines at Butte, and are to be commended as good and useful exercises in subterranean topography. In the State of California mineral industries have developed in so many new directions that gold-mining, though still important, no longer holds its former prominent position. The central feature of the collection is a grotto-like structure built up of blocks of lepidolite or lithia-mica, containing radiating masses of pink lithia tourmaline. This very beautiful rock, which for some time was only a mineralogical curiosity, has now become of economic importance as a source of lithia. The Pacific Coast Borax Company have a large exhibit of borax in the different forms prepared for sale. This is not strictly a California mineral, it being derived from lake-deposits in the desert region of Nevada, but the refining is entirely carried out on the Pacific Coast.

The South Dakota collection is mainly illustrative of the mining region of the Black Hills, where the famous Homestake mine is situated. It includes a very complete topographical and geological model of the region, and specimens of the ores from the principal mines, showing the range of the minerals in depth. In connection with this, a full-size stamp-battery, with amalgamating plates, slime-separating arrangements, and cyaniding-vats, has been provided in the Gulch, where the whole of the operations of gold-recovery by battery amalgamation, followed by the cyanide process, are shown in action. This very complete exhibit is due to the skill and energy of the members of the Black Hills Mining Men's Association; and in order to insure continuous working under conditions resembling those of actual practice a supply of 1500 tons of ore has been contributed by the different mine-owners. It is to be hoped that visiting members of the Institute will not fail to see this, one of the interesting features of the show.

Near the south end of the main central aisle, Block 40, will be found the collective gem exhibit of Messrs. Tiffany & Co., organised by Mr. G. F. Kunz. This contains a full series of the ornamental minerals obtained in the United States, most of them of great beauty and value. The most striking novelty is a transparent spodumene of a delicate violet hue, which has been found in large crystals in California, and has received the name of Kunzite. When cut it gives a gem of a pinkish amethystine colour, but of a higher lustre than amethyst. Adjoining this is an exhibit of radium minerals, also organised by Mr. Kunz for the United States Geological Survey, in which all the radioactive substances known up to the present time are represented.

FOREIGN COUNTRIES.

The contributions of foreign countries vary very much in character, some of them, notably Japan, Canada, Mexico, and Brazil, having sent collections illustrative of mineral industries as complete as could be, while the older European countries have for the most part been content with exhibits of special objects, without regard to systematic completeness.

The Mexican collection, which is first encountered on entering the building from the north side, is essentially a museum of economic mineralogy, the specimens being arranged in showcases intended to be permanently housed in the City of Mexico. These, as may be imagined, are largely silver and gold ores, all the older mining regions being well represented, including plans and sections of the Real del Monte, and other famous mines. Copper-mining, which is of comparatively recent origin, is represented by the Boleo Company of Lower California, who contribute examples of ores, regulus, and black copper, but on a much smaller scale than the collection shown in Paris in 1900. Adjoining this is the exhibit of the Cananea Copper Company, of Sonora, containing some extremely fine specimens of native copper and rich ores, together with furnace products. A third contribution of the same class is that of the Tezuitlan Company, of Pueblo, who, in addition to mine and furnace products, send a series of transparent photographs, illustrating their works in which the Manhés converter comes out remarkably well. The motive power of the works is obtained from Pelton wheels aggregating 1350 horse-power. The iron industry of Mexico, though small, is satisfactorily represented by the contributions of the Monterey Iron and Steel Company, and Mr. Richard Honey, of Zimapan, who sent cases containing small sections of bars twisted and other specimens showing the excellent quality of the material produced. A more characteristic Mexican product is the translucent variegated marble, formerly known as Mexican onyx marble, but which is now more generally called onyx, without fuller qualification. This is very fully represented in the ordinary greenish and buff-coloured variegated varieties, but in one case the marking and colouring are of such a character as to resemble an actual onyx or agate. Such examples seem, however, to be uncommon. A portion of the court is occupied by a collection illustrating the method and work of the Geological Institute of Mexico, an establishment which, although young, has done remarkably good work in assisting the development of the mineral resources of the country.

The Argentine collection includes numerous examples of gold, silver, and copper ores, most of which, however, are awaiting development. There is also a fine display of onyx marble, which appears to be abundantly distributed.

The Brazilian court has an exceedingly interesting display of the iron ores of Minas Geraes, which, although undeveloped, are remarkable as minerals. The principal ore is an almost absolutely pure hæmatite in brilliant mirror-like plate, and "iron roses" up to 5 or 6 inches in diameter. Magnetite and martite or octahedral hæmatite are also commonly found. These ores occur in the older crystalline rocks, and are remarkable for their stability and resistance to atmospheric change.

This is well seen in a specimen of the secondary limonite, formed by weathering action at the surface. This is made of fragments of the hard slaty ore, connected together by atmospheric rusting, the fragments being but slightly, if at all, altered. It is easy to understand from such examples how the attempt to smelt these dense ores in the Catalan forge was entirely unsuccessful. The new and important industry of manganese-mining in Brazil is represented by large and massive specimens, not only from the pioneer establishment of the Usina Wigg, at Miguel Burnier, but from several new deposits. One of these, sent by the Morro de Mina Company, is stated to show an exposure of 5,000,000 tons of solid ore available for removal by railway. Quartz crystals for opticians' use are sent from many different localities, and there is an extremely fine specimen of quartz with inclusions of rutile and other minerals, and other ornamental objects together with zircon and topaz as gems. Monazite sand is another important Brazilian mineral. It occurs in the beaches along the sea-coast in the province of Bahia; and as such is held as a State property, the working being let to contractors at a royalty.

Peru has a small collection, the most interesting feature being the revival of the famous Cerro de Pasco silver-mines, which are now developing as important copper-mines in depth. The working of these mines on a large scale has only become possible since the completion of the railway, which connects the district of Oroya Pass with the Pacific at Callao.

The principal feature of interest in the French court is the model of the Héroult electric steel in use at Froges, together with specimens of steel and iron produced by the process. These include metal of all degrees of hardness from almost absolutely pure iron to cast iron with 4 per cent. of carbon. The furnace is of the well-known Héroult form with carbon electrodes of huge section passing through the roof, with the addition of Wellman rockers for casting. The current enters by one electrode, passes into the metallic bath through the layer of slag, forms an arc and flows back through the slag and out through the second electrode, the electrodes being at no time in contact with the metallic bath. It is stated that a 7-ton furnace of the type shown can produce in regular working order about 150 tons of steel per day. Ferro-chromium, ferro-tungsten, ferro-silicon, and other alloys made in the furnace, are also shown, but, unfortunately, the specimens are very poorly displayed, being laid out on the floor, and must be handled individually to obtain any idea of their character. Another series of electrolytic steel and iron alloy is contributed by the

Société Electrométallurgique, of Albertville, Savoy, but no details are given as to the mode of preparation.

The coal-owners of the Saint Etienne district contribute a fine model of the Loire coal-basin made up of transverse sections upon glass plates, together with details of their miners' school, and there are some exhibits from the large collieries of the north of France. These, however, consist mainly of drawings of plant and surface arrangement, the most notable exception being that of the Auchy and Courrières Company, who show a full-size model of the system of temporary support by iron bars in driving levels before the permanent timbering is put in, which has been very successful in reducing the accidents from falls of roofs in the mines of the latter company. Mr. F. Laur sends a series of samples of bauxite classified according to the composition observed by him in the deposits of the south of France, but, unfortunately, they are entirely without labels or description. The Geological Map of the French Alps, placed on the south wall of the court outside, marks the completion of an important and difficult work by the French Geological Survey, and as such is specially noticeable. Mr. L. Couriot sends some of his original radiographs, showing the interstratification of the ash in unburnt coal.

The German court is principally occupied by models which many of the members have already seen at the late Düsseldorf exhibition. This includes the beautiful sectional model of the Ruhr coalfield belonging to the Bochum coal-owners' fund, that of the surface-arrangements of the Shamrock III. and IV., pits of the Hibernia Coal Mining Company, and one of the "colony" of workmen's dwellings of the Gelhausen Company. The housing arrangements for officials and workmen adopted by the Krupp Company are set out in considerable detail by drawings, plans, and photographs, and there is a very full display of literary matter dealing largely with questions bearing on the health and safety of working miners. The Geological Survey of Prussia shows the detailed survey of several complete districts, as well as geological models on a smaller scale of the Harz, Thuringer Wald, and other interesting localities. The only exhibit, however, of any special technical interest is the large collection of safety-lamps by Messrs. Friedman & Wolf of

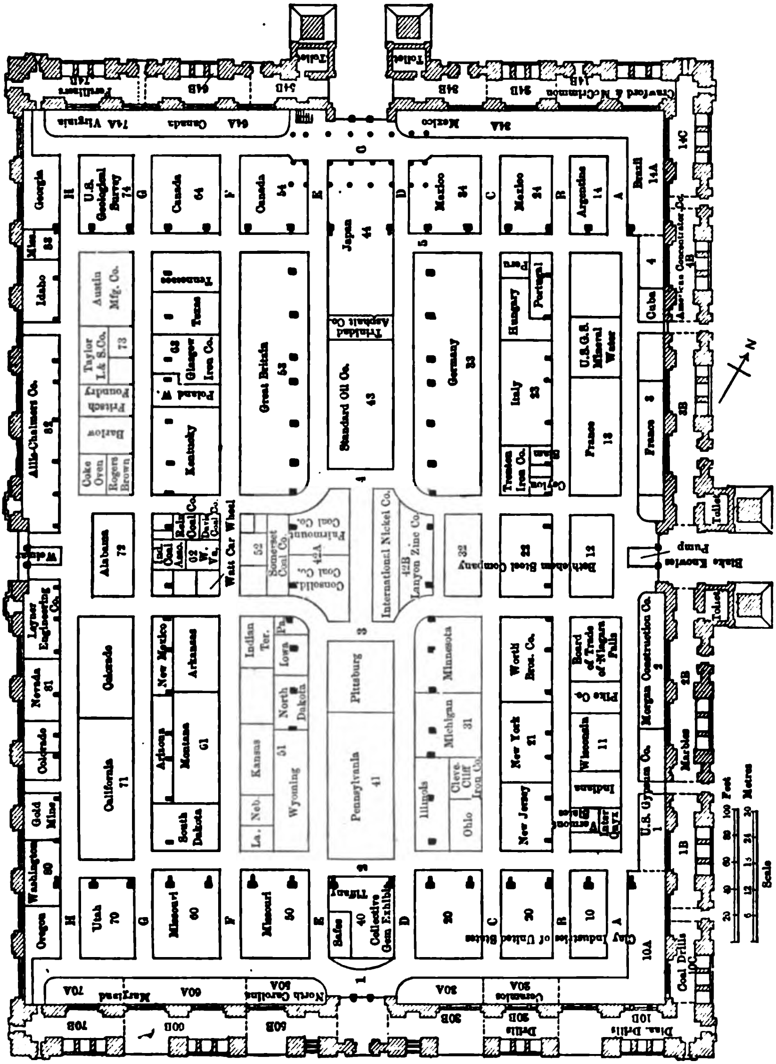
Zwichau, which includes examples of every kind of lamp used underground, whether for lighting or heating purposes, and of the plant and tools for repairing and cleaning in the lamp-room. On the outside will be found a very full exhibit of porcelain objects for chemical manufactures made by the Royal Porcelain Works, Berlin, and there are a few examples of graphite crucible and fireclays, but otherwise the collection is of no great interest.

The Italian collection, which has been arranged by the Royal Corps of Mining Engineers at Rome, is almost entirely confined to two specialties, namely, sulphur and marbles, both being very thoroughly illustrated. In the former subject all the principal producing centres, both in the Romagna and Sicily, are represented among the specimens; a block of native sulphur weighing 1200 lb. cut from a mass in a Sicilian mine is remarkable. The marbles include examples of all the usual kind, both white and coloured, and on the outside of the court a large series of photographs illustrates the methods of working and transport adopted in the Carrara quarries. The Geological Survey of Italy sends a large series of maps, including the new detailed survey of the Island of Elba, and there are some fine photographic views of the new blast-furnaces and coke-ovens at Porto Ferrajo. An exhibit of great interest, which should on no account be missed, is the original Someillier rock-boring machine, the first that was used successfully underground. It dates back to 1860, and was employed in the Col de Fréjus (Mont Cenis) tunnel work, having bored the last hole which joined the headings in December 1870. Although not labelled, this can be easily found, as it occupies a prominent place.

The Japanese collection is a remarkably full and complete display of the mineral resources of the Empire, and the progress made in their systematic study and description by the Imperial mining and geological departments. The largest and most important items are coal and copper. Iron- and steel-works on a large scale have been erected at Fukoka-Kon, but are not as yet in full work. They are represented by a series of views and a case of sections. The most prominent feature in the court is a large model of the Manda pit of the Miike colliery, pit-frame and surface details being fully represented. These mines are extremely heavily watered, 17 tons of water being raised for every ton of coal. The shaft, which is rectangular, with a double hoisting equipment, has a pit-frame 100 feet high, measuring 41 feet by 12 feet, and is 996 feet deep. The output is about 2000 tons per day. The pumping-plant is of an extremely heavy character, including, apart from underground engines, four Davy compound engines, with 45-inch and 90-inch cylinders, each working two lifts of 22-inch pumps, and raising 400 cubic feet per minute. The whole of the details of this model are very carefully worked out, and the engines are shown in motion at intervals during the day. A second interesting model is that of the Takashima coalfield in Nagasaki harbour. This is a deep basin of somewhat complicated structure, the details of which have been entirely ascertained from underground workings; the surface of the ground, with the exception of a few isolated peaks, being entirely covered by the sea. A third model represents the Kosaki copper-smelting and refining-works, which is accompanied by another modelled in the old conventional Japanese style, showing the distribution of the mineral veins in the mines worked by the company. Accompanying these are very full sets of the products of the mines; coal, copper and other ores, and furnace-products, including bar copper and electrolytic refining-products. Sulphur, antimony, and bismuth are among the other metals represented. This collection, which is one of the most complete exhibitions of the resources of a country, suffers somewhat from being overcrowded, which is to be regretted, as much of the adjacent space is very scantily occupied.

The principal feature in the British section is the collection of specimens illustrative of the mining industry of the United Kingdom, exhibited by the Home Office. This was made by Mr. Ware and Mr. Williams of the Mining Department of the Home Office. It contains contributions from two hundred different firms and companies, each contributor being restricted, as far as possible, to a single specimen. The arrangement is the alphabetical one adopted for statistical purposes by the late Sir Clement Le Neve Foster. It is further illustrated by a numerous series of photographs of mine-working, both open air and underground. These are mostly by Mr.

Williams, with a smaller number by Mr. J. C. Burrow. Mr. H. W. Hughes' well-known photographs of South Staffordshire mines form an independent contribution. The Geological Survey, through the Education Department, send a large series illustrative of the recent progress of the Survey, the prominent items being the new map of the North Staffordshire coal-field on the 6-inch scale, and the 1-inch map of the Western Highlands of Scotland, the latter being accompanied by a model of the Assynt district on a large scale. A new model of the Purbeck district embodies the work of Mr. Strahan and others in the revision of the earlier survey, and the 6-inch scale model of London, which has been on view in the Jermyn Street Museum for the past thirty years, has also been sent. The Geological Survey of India is represented by a selection of its latest works and publications, and the magnesite and manganese ore deposits of Southern India, which have developed into important sources of supply of the like minerals through the initiative of Mr. H. G. Turner, are illustrated in the exhibit of Messrs. Macfadyen & Co. The metallurgical exhibits include two small but effective cases, contributed by the Monkbridge and Farnley Iron Collieries, illustrating Best Yorkshire iron, while Shropshire and Derbyshire are represented by the Lilleshall and Sheepbridge companies respectively. The microphotographs prepared by the late Sir William Roberts-Austen, in illustration of the reports made to the Alloys Research Committee of the Institution of Mechanical Engineers, form part of the Board of Education exhibit; but the large and important series of the same kind by Messrs. Stead, Harbord, and Campion, and the Great Eastern Railway Company, are included in the general exhibition of British scientific photography in the Liberal Arts Building. The Board of Agriculture in Ireland contributes a very fine series of Irish economic minerals, mainly building-stones and marble. There are two other British marble exhibits, both representing the rediscovery of ancient quarries, one being the dark fossiliferous marble of Durham, sent by the Harehope Mining Company, and the other the famous Verde Antico marble of Thessaly, which locality was rediscovered a short time back by Mr. William Brindley. The latter exhibit, however, is not in the Mines Building, but in that devoted to Varied Industries at the opposite side of the grounds.



Ground Plan of Exhibits in the Mining and Metallurgy Building.

The mineral collections exhibited by the Dominion of Canada are very striking and effective. This is partly due to the commanding position and the absence of any enclosing wall, but more particularly to the great variety included and the skilful arrangement adopted. In it will be found coal from Nova Scotia, the Western prairie region flanking the Rocky Mountains and the Pacific, iron ores from Nova Scotia, Quebec, and Newfoundland, nickel ore from Sudbury, and gold from Nova Scotia, British Columbia, and the Yukon. In connection with gold-mining, an interesting model by Messrs. Faribault & Roberts, illustrative of the distribution of the rich zones in the Nova Scotia gold-mines, in which the experience obtained in the Saddle Reefs of Bendigo, Australia, has been applied to working out a very puzzling problem, deserves mention. Mica, corundum, asbestos, and apatite, which are important Canadian specialties, are worthily represented, the mica display being especially fine. There are also some large crystalline masses of feldspar in large regular cleavage fragments nearly 7 feet in length. In addition to the well-known nickeliferous, magnetic pyrites of the Sudbury district, there is an interesting new discovery of nickel and cobalt ores, in which these metals occur as arsenides, together with native silver, an association similar to that of the Saxon and Bohemian mines.

The Ceylon collection, although small, contains a very thorough representation of the staple mineral of the island, graphite, together with a model of one of the principal mines.

In concluding these somewhat hasty remarks, the writer desires that they may be in no way considered as a complete and critical review of the subject, the object sought being that of assisting visiting members not having much time at their disposal to pick out those sections likely to be of most interest to them, and for which purpose, with the assistance of the plan, it is hoped that they may serve to be of more service. He also wishes to express his thanks for courtesies received from Dr. Holmes, Mr. H. A. Wheeler, and the gentlemen in charge of the different State and foreign collections.

A vote of thanks having been accorded to Mr. Bauerman, the following paper was read :—

A WEST AFRICAN SMELTING HOUSE.

BY C. V. BELLAMY, M.INST.C.E., M.I.MECH.E., F.G.S.,
DIRECTOR OF PUBLIC WORKS, LAGOS.

IN these days of advancement, when the manufacture of iron from the extraction of the ore through all the processes of preparation, of smelting, refining and tempering, until it has reached the condition in which it is met with in everyday life, has been made the special study of some of the leading men of the day, whether engineers or physicists; when the great manufacturing firms of the Old and the New World vie with each other in sending their wares to all parts, and can put them on the markets at a price but a trifle above the cost of production, it is seldom that smelting works, conducted after the crude manner of the ancients, are met with; and it is difficult to realise that such places can still have an existence in a part of the world which is within twenty days of the great manufacturing centres of Europe.

Yet to-day there is, in the hinterland of the British colony of Lagos, West Africa, not more than three days' journey from the coast, a small village whose inhabitants have been engaged in the extraction of iron for generations past, and where the methods are the same, probably, as those practised by the earliest workers in this metal. There is no suspicion throughout the whole of this small community of any modern improvements, and there is nothing to suggest in the character of their implements or appliances that they have been in any way influenced by suggestions from the outside world.

The people follow the habits of a life which, measured by our standard, would be termed savage, yet the existence of an industry such as is herein described removes from them this stigma. They are simple and unsophisticated, but they practise an art which is unknown to the savage and which places them high above him in the social scale, while it entitles them to be considered to have reached a higher degree of civilisation than many of the tribes met with in European countries where the people have been looked upon for many years past as more domesticated than any of the inhabitants of the Dark Continent.

Although these smelting works are situated within one short day's march of Oyo, the capital of the Yoruba country and the seat of the Alaffin or king of that nation, it is only recently that they have been visited by a white man, for the first time, in the person of the Rev. Mr. Pinnock, the representative at Oyo of the Baptist Missions. It is to this gentleman that the writer is indebted for the information which led him to visit the place in the company of Mr. J. E. Stone, of the Public Works Department, Lagos.

Before making the expedition it was necessary, as an act of courtesy to the king, to obtain permission to do so, through the medium of the Aremo, the eldest son of the Alaffin, who stands in relation to his father much in the same position as the crown prince of a royal house of Europe. The king himself is now advancing in years, and much of the petty detail of executive work is relegated to his eldest son. Through the good offices of the Rev. Mr. Pinnock this permission was secured, and a guide, one of the native evangelists of the mission, having been provided for the party, a start was made on Monday, the 15th of February, from Oyo at 7.30 in the morning.

The town of Oyo is situated at a distance of 35 miles to the northward of Ibadan, which is the upper terminus of the railway, and which may be reached by a journey of ten and a half hours in the train from the capital town of Lagos; the distance from Lagos to Ibadan is about 126 miles. The smelting village is therefore about three or three and a half days' journey from Lagos, which is reached by steamers from Liverpool, trading to the west coast of Africa, in about seventeen days or less.

Leaving Oyo and following an ordinary bush path in a direction almost due north, a tract of country is crossed in which there are very few habitations and where not more than two or three farms for the production of cotton, maize, yams, &c., have been established. The greater part of the country is covered with stunted trees and coarse reed-grass, and here and there the landscape is blackened by recent bush-fires which have cleared large areas of country, but occasionally narrow belts of forest occur in the valleys, where the trees have reached more substantial dimensions. Except for these belts, the broadest of which marks the course of the Awong River, a tributary of the Ogun, now dry, but during the rainy season a stream of some importance, the whole extent of the country may be included in the somewhat comprehensive term of Bush. The path is so narrow in some places that the hammock-chair, so much in vogue as a means of conveyance in this part of the world, cannot pass without being tilted up sideways, to the discomfort and inconvenience, and sometimes even to the expulsion of the occupant.

The topographical features of the country are not striking, and only in a few instances is the evenly undulating nature of the landscape broken by a more conspicuous boss of gneiss, rising bare and treeless, above the surrounding foliage. The soil gives evidence from time to time of the presence of laterite, of quartz, and of hæmatite or specular iron, all of which are met with throughout the greater extent of the protectorate; but there are few evidences suggesting the presence of other or more precious minerals. Throughout the journey the rock, wherever it was encountered, is foliated gneiss.

After a march of about four and a half hours, evidences of charcoal-burning seemed to point to the proximity of our quest, and steps had to be taken to send ahead to warn the villagers of our approach and to explain that we desired to come in peace and to go in peace; that we sought to do them no injury, but to sit down in their village and amongst them for a space. This precaution is still necessary in many of the villages in these parts, because the natives, being frequently extremely suspicious of strangers, will sometimes abandon their houses in a body and conceal themselves for days in the bush until the disturbing element has passed on. Our ambassador, the evangelist, performed his office with success and to the satisfaction of all parties, and upon our arrival, after about five hours' march, covering a distance, probably, of some 16 or 17 miles, we found the people well disposed towards us and eager to offer us the hospitalities of the bush.

The community consists of about a hundred or a hundred and twenty souls, and beyond the cultivation of a few acres of provision-grounds for their daily requirements, the whole of them—men, women, and children down to the ages of five or six—are occupied in the mining, smelting, &c., of iron. They have followed this avocation, as a separate tribe, apparently for generations, though not always in this same neighbourhood. The balé, or headman, explained that at one time they were located to the southward of Oyo, close to the small village of Menea, between that town and Ibadan, where there are numerous evidences of smelting works to be seen on the side of the bridle road joining the two places; but that about five years ago, say in 1898 or 1899, they migrated to their present location, where the iron ore is of better quality and easier to work. They call their village Ola-igbi; it is situated on the south bank of a river known as the Omi, which falls into the Ogun about 10 miles to the westward. This latter river, after passing the important town of Abeokuta, falls into the Lagos Lagoon, in the neighbourhood and slightly to the west of Ikorodu.

To the eastward of the village the valley forks, and on the ground between the two streams, or more correctly, water-courses, since they are now dry by reason of the exceptionally dry season, the crude ore is mined in a manner strongly suggestive of the ancient stream-workings in Devon and Cornwall, and elsewhere. In mining parlance it may be described as "placer"; the ferruginous deposit is met with at a depth of not more than from 6 to 8 feet below the surface of the ground, and occurs in a shale which is closely associated with the neighbouring gneiss rock. This shale is much broken up, soft, friable, and laminated; the laminæ suggest alluvial influence, but it would seem that this feature is in no very marked degree different from that of the foliated gneiss in the immediate neighbourhood.

Above the shale is a layer of about 6 feet of gravel, largely composed of nodular particles of hæmatite iron mixed with reddish clay. Occasionally among this gravel are found water-worn fragments of quartz, frequently stained with iron, and often incorporating particles of felspar in a decomposed state, as well as mica and other minerals.

The shale is excavated, with the aid of a rude pick, in pieces weighing from 3 to 5 pounds, and is carried to the smelting works for treatment. This consists, firstly, in roasting it over a fire of green timber. This generally takes place at night, the small fires for the purpose being lighted up about sunset, and then left to take care of themselves until the morning, when the ore is ready for further treatment. There is nothing novel or remarkable in this operation. The fires are constructed of about a dozen logs of wood, perhaps 6 feet long, and 9 or 10 inches in girth, piled one above the other, and on the top are laid pieces of the crude ore in the condition in which it has come from the workings. The quantity of ore on each fire hardly exceeds a barrowful. The next morning the ore is pulverised in an ordinary wooden mortar, such as the natives use for pounding yams, &c., with the aid of a pestle of the same material, both shaped in the rudest manner. This is done by women and children, who seem to take to this work as soon as they are strong enough to wield the pounder.

The poundings are screened until there is nothing remaining in the mortar, the sieve consisting of a native-made basket, rather openly woven, and they are then borne away to the river-side for the purpose of washing or panning. This is carried out by women in the following manner: a hole is dug in the ground about 2 feet deep, and about 2½ feet in diameter, and is filled with water to within about a foot of the top. Into this one of the women descends, provided with a calabash tray about 18 inches in diameter, into which she pours a quantity of ore poundings sufficient to half-fill the tray. She proceeds to wash this by means of a circular oscillating motion, which causes the contents of the tray—ore and water—to follow a circular course, by means of which the lighter, finer, and probably largely organic, matter is discarded, and falls to the bottom of the pit, while the heavier particles remain in the tray. When this has undergone washing sufficiently in the pit, it is set aside on the bank for a further and more careful washing by a second woman seated on the ground near by. This second treatment consists in placing it in another tray and sluicing it in clear water, and agitating it until the water drawn off is clear and free from colouring matter. The ore is then deemed ready for the cupola, and the residue of finer material, which is of a rich dark-red hue, and may be termed the tailings, is thrown away. The washed ore is conveyed to the smelting house and poured into the kiln, as occasion may require, in a damp state.

Having described the process of mining and treating the ore up to the time it is ready for the cupola, it now becomes necessary to give some particulars of the smelting house, and of the methods followed there. There are in the village altogether eleven smelting houses, and as each is an exact reproduction of the other, it will only be necessary to describe one. Each shed measures from 25 to 26 feet in length, by about 16 feet in width, a doorway being provided at each end. The walls are built of clay-daub, and vary in height from 4 to 6 feet; they are not carried up to the roof, but a space is left all around for light and ventilation. At irregular intervals, around the walls, and built in the thickness of the same, rough posts are placed to carry the eaves of the roof, while the ridge is supported by

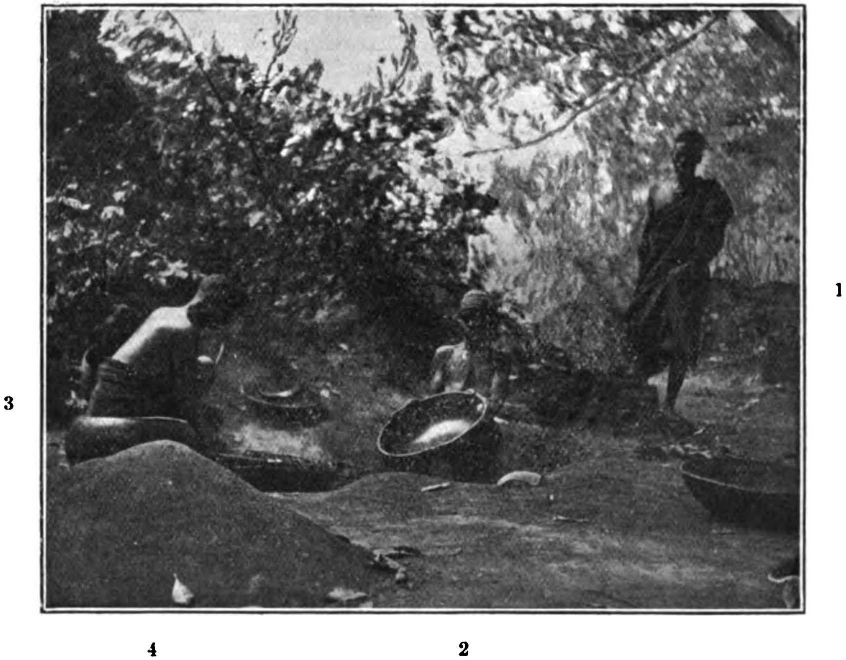


FIG. 1.—Washing the Pounded Ore.

1. The head smelter. 2. Woman standing in well, giving the ore its first washing. 3. Woman seated on ground, giving the ore its second and final washing. 4. A heap of pounded ore waiting to be washed.

two other posts planted in the interior of the hut, and steadied in each case by a rude tie-beam spanning the building from side to side at the eaves. From ground level to ridge the height is about 25 feet, so that, although the roof is covered with a thatching of palm leaves, there is little chance of its becoming ignited by the flames from the cupola. These smelting houses are, in nearly every case, placed east and west along the longer axis.

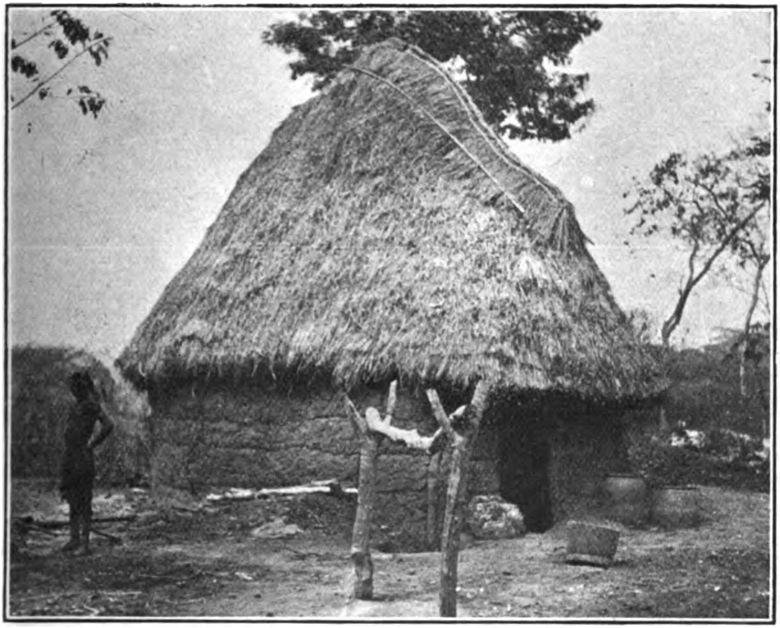


FIG. 2.—Exterior of a Smelting House.

The principal feature of the interior is the cupola, which stands about the centre of the shed. It is built entirely of clay in mass, and occupies a circular space, whose diameter is from 7 to 7½ feet; the height of the cupola from floor level to the crown of the dome is about 3 feet 9 inches. On the eastern side and facing one of the doorways is the entrance to the cupola, the sill of which is about a foot below the floor, and an irregularly-shaped depression in the floor, about 4 feet long and

3 feet 4 inches wide, is provided to give access to the doorway, and therefore to the interior of the cupola. This doorway, the entrance to the furnace, occupies about a fourth part of the circumference of the cupola, and around the remaining three-fourths there are seven rough counterforts, each measuring about or rather less than a foot every way, alternating with six openings through the walls of the cupola, each about a foot and a half high, and nine tapering to 6 inches in width; the entrance to the cupola, therefore, occupies the width required for one counterfort and two openings. The sides, top and bottom of each opening slope inwards and downwards towards a point about the centre of the base of the furnace.

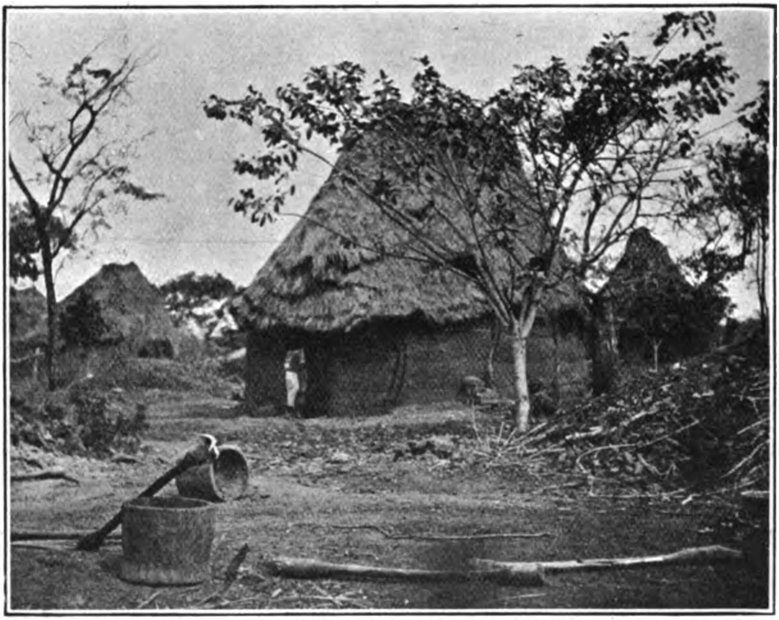


FIG. 3.—View of Smelting Houses. In the foreground are two wooden mortars and a number of pestles used for pounding the ore.

The dome of the cupola is rounded up on the outside slightly, and measures about 3 feet 6 inches to 3 feet 9 inches across, and a circular orifice or flue is left in the centre of the dome about 9 inches in diameter. A short distance below the curve of the dome a rope of twisted vines or creepers is passed round the cone and pegged down into the clay for the purpose of binding the walls securely together and preventing them from cracking and opening out, in the same manner in which an iron band or strap is applied to the cupolas of more civilised countries.

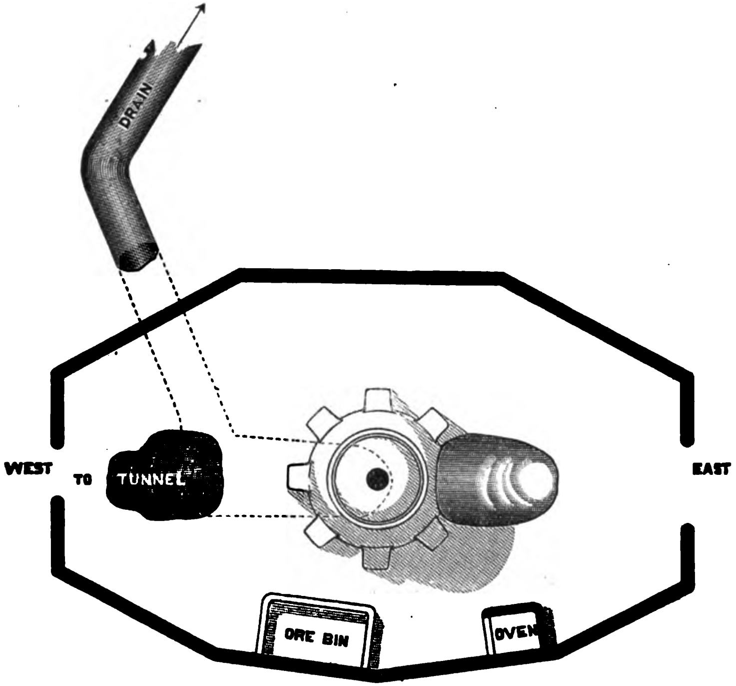


FIG. 4.—Plan showing Arrangement of Shed. (Scale, ⅛ inch to 1 foot.)

The interior of the cupola measures in its greatest diameter about 2 feet 6 inches at a height which corresponds to the floor level outside, and the floor or bottom of the furnace, which is rounded, is about 2 feet below this point. The height of the furnace is about 5 feet, and the space is of an elongated egg-shape in section; the surface is rendered smooth with clay. The larger rounded end is, of course, at the bottom, and the sides taper inwards on easy curves toward the flue in the crown of the cupola.

In the centre of the bottom of the cupola is an aperture about 3 or 4 inches in diameter, which communicates with a short tunnel below the floor of the shed, to which access is had by means of a pit immediately inside the western entrance to the shed. On the northern side of this tunnel a branch is provided, passing out underneath the walls of the shed and communicating with an open drain, which is provided for the purpose of carrying off any moisture which might accumulate in the tunnel during the rainy season.

There are two other permanent features of the interior of the shed, one consisting in a small vertical oven about 2 feet 6 inches long and 1 foot 10 inches wide by 4 feet in height, roofed in and enclosed on all but one of the narrow sides. This is employed for firing the earthenware pipes, each about 2 feet long and 1½ inches internal diameter, through which the draught is led into the centre of the fire when the cupola is working. The other fixture is merely an ore bin about 4 feet 8 inches long and 2 feet 8 inches wide, the walls of which are about 9 inches high. In both cases these fittings are constructed of clay-daub, no stone or brick being employed for any purpose connected with the shed or its fittings, and even the tunnel is cut in through the soil and has no other support but that of its own strength, though it has to carry some share

FIG. 5.—View of Exterior of Shed.

of the weight of the cupola above its inner end. Around the rest of the shed the wall-space is occupied with stacks of charcoal, calabashes of flux and metal, tools, pestles, and mortars, and a miscellaneous assortment of articles.

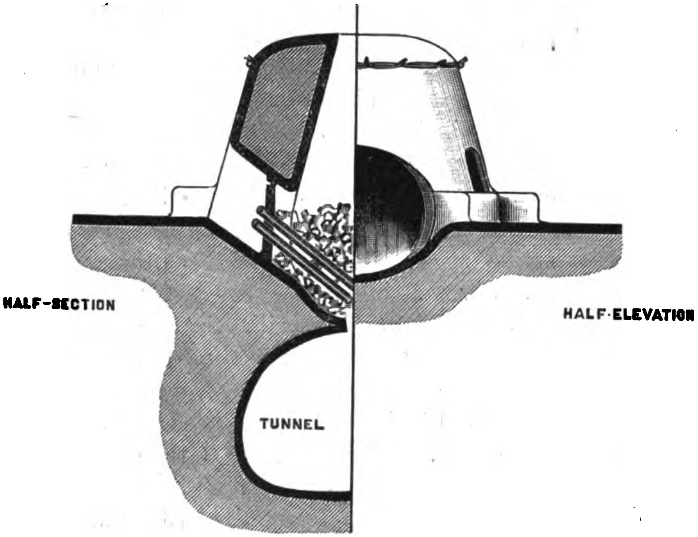


Fig. 6.—Details of Cupola

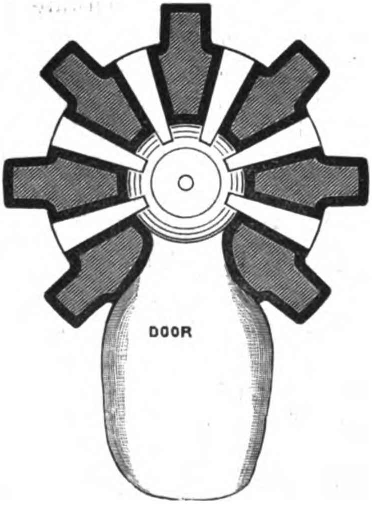


Fig. 7.—Plan. (Scale, ½ inch to 1 foot.)

The process of smelting occupies a period of about thirty-six hours. A cupola is charged about daylight of one day, and is drawn off shortly after sunset of the following day. The first operation in preparing a cupola for smelting consists in closing the six vertical apertures. This consists in setting in each of the apertures two earthenware pipes, one above the other, built around with charcoal, inclining downwards towards the centre of the bottom of the furnace where all the pipes concentrate; the opening is then sealed with clay to the thickness of about a couple of inches, but the entrance to the furnace is not closed until the last moment. On the following morning about daylight, or say 5.30 A.M., the actual charging of the cupola commences, firstly by closing the orifice in the bottom of the furnace which communicates with the tunnel, this being done with the aid of a cone of damp sand, roughly shaped with the hand, and forced upwards into the orifice, and caulked tightly with the same material. Live charcoal is then placed in the centre of the cupola and the firing started; as soon as this is accomplished and the fire properly established, proceedings are taken for the closing of the door of the cupola. In this instance there are fixed three pairs of earthenware pipes in positions corresponding with those fixed in the six vertical apertures around the cupola. They are, as in the other cases, packed around with charcoal and finally built around with a clay seal of a thickness corresponding to that adopted in the other cases.

The result of closing up the openings and of confining the inward flow of air to the pipes is immediately apparent by a brightening of the flame and a more brisk heat. It will be seen that there are altogether nine pairs of pipes supplying the necessary draft to the fire, and although they are only rudely shaped by hand around a stick, and but partly baked, the average diameter of each pipe is about 1·40 inches. This gives a sectional area of, say, 1·54 inches, and as there are in all eighteen pipes supplying the indraft, and the opening in the crown of the cupola is 9 inches in diameter, the relationship between the inflowing current of air and the escape in the dome is in the ratio of:—

$$\begin{aligned} &18 \times 1{\cdot}54 :: 9 \times 9 \times 0{\cdot}7854 \\ &= 27{\cdot}72 :: 63{\cdot}6174 \\ &= \text{say, } : 3 :: 7. \end{aligned}$$

That is to say, that the outlet is two and a third times as great as the inlet; by this means a description of forced draft is obtained in a very simple but effectual manner.

As soon as the fire in the cupola is well established, a condition which is quickly fulfilled as soon as the openings in the lower part are closed, a flux is thrown on to the fire through the flue in the crown of the cupola. This flux is obtained from the slag or refuse clinker from each successive smelting. How it was first obtained the headman of the village was not able to explain, but he stated that it increased as time went on, because the yield of flux from each smelting was more than sufficient for any one subsequent operation. He acknowledged that, without the aid of the flux, they would not be able to carry on their work, and that if, by any misfortune, they became deprived of all their flux, their industry would cease. He further added that when they migrated to their present location they brought with them a quantity of flux from their former workings. The discovery of this important element dates probably many centuries back, possibly to the days of the first workers in the metal, and is now, unhappily, shrouded in obscurity. It is, however, now reproduced at each operation immediately before the cupola is opened and the smelted metal drawn out. The process of its collection will be better understood when an explanation has been given of the treatment of each firing; it is perhaps the most important feature of the whole process.

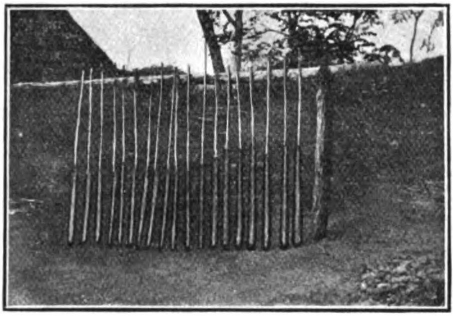


FIG. 8.—Earthenware Flue-pipes drying in the Sun.

It has been explained that a cupola commences to be charged at daylight, about 5.30 A.M., and about two hours afterwards, when the fire is well alight, a quantity of flux, about 5 pounds in weight, and about 2 bushels of charcoal, are thrown on to the fire. After a further lapse of about two hours, or, say, about 9.30 A.M., this flux is drawn off through the aperture in the bottom of the hearth communicating with the tunnel, and a similar quantity of flux as before, together with a similar quantity of charcoal, are added. This makes two charges of flux before any smelting is commenced. Again, about two hours later, or, say, 11.30 A.M., this flux, the second charge, is drawn off, after which the fire is considered to have undergone sufficient cleaning, and the real operation of smelting commences.

FIG. 9.—Two Pigs of Metal as they have come from the Cupola.

Firstly, about 5 pounds of flux is applied, then about 2 bushels of charcoal, the quantities being the same as in the former charges, but immediately afterwards a quantity of iron ore of the same weight as that of the flux, say, 5 pounds, in the washed state, and still moist, is thrown into the cupola.

This operation of feeding the cupola with ore is repeated ten times from start to finish, but, prior to each charge, the flux is drawn off in the manner already described, and only upon the ninth and tenth, the final charging, and also immediately before the cupola is emptied, is the flux reckoned of any value for assisting in subsequent smeltings. These are, therefore, the residue of the eighth, ninth, and tenth charges. There are therefore three occasions during each firing when flux may be collected, and it may well be understood that the supply exceeds requirements. Yet upon each draw-off there is a considerable quantity of dross which is thrown to spoil, and there appears to be a certain amount of judgment required to discriminate between what is worthless dross and what is serviceable flux.

The quantity of ore put in at each charge gradually increases —using the words of the head smelter—from "the third part of a calabash," *i.e.* about 5 pounds in weight, to "a full calabash and a half," or, say, about 25 to 30 pounds of ore, which maximum is reached upon the eighth charge, the last three being equal. The precise moment when the fire is ready for the reception of each successive lot of ore is a matter entirely of judgment and experience, but the interval is usually from two to three hours, a period of five hours being allowed to elapse between the last or tenth charge and the opening of the cupola. The only explanation offered in reply to my inquiries was that the fire, as seen through the flue, must be white.

FIG. 10.—Breaking up the Pigs into Convenient Sizes (by the woman in the centre with the aid of a stone).

At the appointed time, and as soon as the cupola gives indications of being ready to be opened, one of the attendants descends into the tunnel communicating with the bottom of the cupola, and, with the aid of an iron pricker, opens out the orifice in the bottom, thus allowing the flux to run off. The orifice is kept open and clear by means of the pricker until the flux has ceased to run. The last of this flux seems to be considered to be the best, and is without further examination set aside for use, but the first lot of the run-off, which may weigh as much as 40 pounds, is set apart for closer examination by daylight.

Then preparations are made to open the cupola, and, with the aid of a wooden crow-bar shod with iron, the clay seals over the six apertures are broken up, the earthenware pipes removed and thrown to spoil, and finally the doorway of the furnace is opened. The contents of live charcoal are raked out through the doorway with the aid of a wooden scraper, they are then drenched with water, and carried away. Then the smelted metal is revealed lying in the bottom of the furnace in a solid cake or pig. After a good deal of manœuvring, and when nearly all the charcoal has been withdrawn, a loop of green creeper from the forest is thrust in and hooked over the cake of metal, and by this means the latter is drawn forth out of the cupola, and eventually out of the shed, in a red-hot state, and is allowed to cool off until the following morning. Subsequently it is broken up into convenient sizes and taken to the market, where it is bought up by the blacksmiths, who do the necessary puddling themselves.

The quantity of ore employed from first to last in charging each cupola, taking the figures very approximately, and accepting the evidence of the head smelter, would appear to be as follows:—

For the	first	charge,	about	5	lbs.
,,	second	,,	,,	7½	,,
,,	third	,,	,,	10	,,
,,	fourth	,,	,,	12½	,,
,,	fifth	,,	,,	15	,,
,,	sixth	,,	,,	17½	,,
,,	seventh	,,	,,	20	,,
,,	eighth	,,	,,	25	,,
,,	ninth	,,	,,	25	,,
,,	tenth	,,	,,	25	,,
	Total .	.		162½	lbs.

The weight of each pig of smelted metal as the yield of each operation would be, as near as one could judge, between 70 and 80 lbs. Taking the average yield at, say, 75 lbs., the ratio of metal to crude ore is as $75 : 162 = 46$ per cent. That is to say, that for every 100 lbs. of ore thrown into the cupola 46 lbs. of metal are produced. The remaining 54 per cent. of ore comes away in clinker from which the necessary flux for subsequent smeltings is selected, and the residue thrown to spoil.

Probably the most remarkable feature in the whole of the process is this use of selected clinker for a flux. This may throw light upon what is now frequently a matter of doubt—namely, the medium employed by the ancients in their smelting operations.

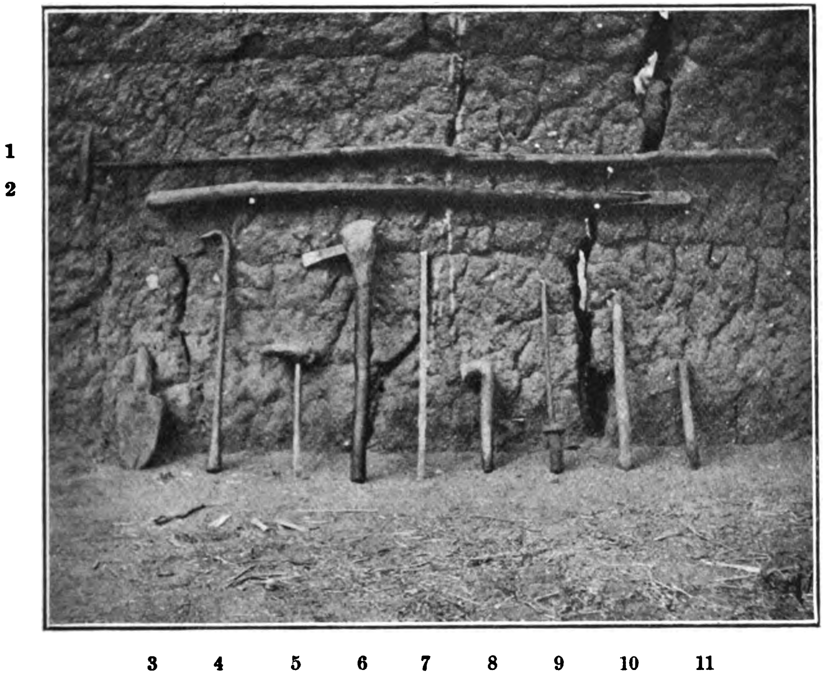


FIG. 11.—Tools, &c., used by the Smelters.

1. Wooden scraper for raking out the fire. 2. Wooden crowbar with iron shoe. 3. Wooden trowel for handling hot clinker and flux. 4. Iron hook for hooking out the slag. 5. Iron pricker for opening hole in bottom of furnace; wooden handle. 6. Axe for chopping wood. 7. An English two-foot rule to give scale. 8. Hammer for breaking up pig iron. 9. Iron pricker with wooden handle, used in the same way as No. 5. 10, 11. Wooden bars for opening or closing the air inlet pipes. The iron of which these tools are made is produced locally.

The head smelter in the course of many conversations on the subject showed himself to be extremely intelligent and both eager and willing to supply any information sought, as well as to show and explain every operation as it took place. Amongst other things he said that to the best of his knowledge there were no smelting works in this part of West Africa, and that, indeed, he had never heard of any existing anywhere else. He said that they supplied all the markets in the neighbourhood, mentioning such large centres as Oyo, Ogbomosho, Isseyin, Ibadan, and down as far south as Ijebu Ode, an extent of country covering some hundreds of square miles.

As has already been indicated, the pig iron, after it has cooled down sufficiently, is broken up into convenient lumps for the purposes of sale or barter, and beyond this undergoes no change whatever from the time it leaves the cupola to the time it reaches the smith's shop where the puddling is done. In order to witness this part of the work a visit was paid to a smithy in the town of Oyo on our return thither, and here again everything was of the most primitive character.

The bellows consisted of a pair of circular wooden bowls about a foot in diameter, connected by an air passage constructed of the same, from which two wooden pipes, to do duty for the tue-iron, lead to the hearth; over the top of each bowl is loosely secured an undressed goat-skin, to which is fastened in the centre of the bowl a long bamboo rod, one of which is held in each hand. The skin is very slack, and by raising and lowering the rods alternately a more or less continuous current of air is supplied to the hearth. There is no inlet valve to these bellows, and the air supply enters by the wooden tue-pipes, a space being left between the hearth stone and the nozzles for the purpose; the bellows and hearth rest upon the ground.

The other fittings of the smithy were of a similarly primitive character. For heavier work a large smooth, undressed and water-worn stone does duty for an anvil, but for smaller work another anvil is provided like a silversmith's, made of metal produced locally. The hammers look at first sight like so many rude lumps of iron roughly handled with the same, but a closer inspection shows them to be systematically shaped and diamond-wise in section so as to expose a flat or a straight pane by a single turn of the wrist; it is of an ingenious pattern.

With such simple means as these the smith puddles the iron which is smelted after the manner already explained. To put this to the test, a piece of the rough metal as it had come from the smelting works was selected from the odds and ends in the smithy and handed over to the smith with instructions to puddle it up and shape off one end leaving the other rough and untouched. This he did without any hesitation or further preparation in the space of a few minutes, the only precaution taken being to warn the bellows-man to blow gently at first and to accelerate the speed as the metal became hotter. The results were satisfactory as well as instructive, and the specimen was brought away to join the others which had been collected at the smelting house.

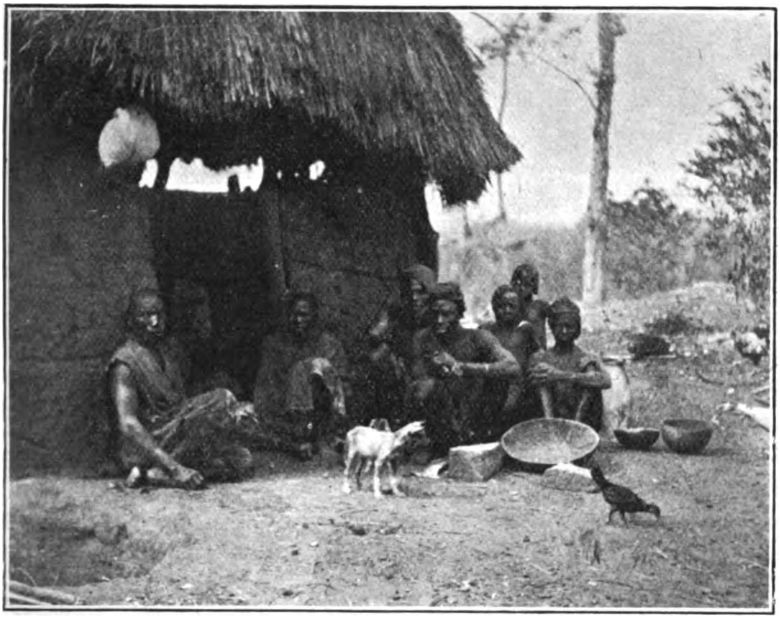


FIG. 12.—Group of Smelters.

Getting into conversation with the smith, he explained that all the metal he used came from the smelting works which we had just visited, at Ola-igbi; there was no regular price paid for it as there is no standard of weights and measures in the country, but it is exposed for sale in little heaps: this for threepence, that for sixpence, and so on. He could not give any idea of the market value of the metal, but of this some notion had been gained at the smelting works where, as we stood to witness the pig being drawn out of the kiln, we were told that the yield was good and would fetch about ten shillings. We judged that the weight was about 60 lbs., at which rate the price would work out at 2d. per lb., or £18, 13s. 4d. per ton, or perhaps six times the price of pig iron on the English market.

Among the miscellaneous articles in this native smithy there happened to be an English rose-head nail, and for curiosity's sake we asked the smith what he thought of such metal. His reply was of the most emphatic character, "It is no good!" He repudiated with striking scorn the suggestion that he might use such metal for making tools for native uses, but his reply was the same. His own native metal was good, always good, good for all kinds of tools, and he would not use English iron as it was no good for the tools that he made, hoes, axes, &c.

In the case of another smithy which we visited in a village to the southward, we found the same lumps of native iron from the same works, but here it seemed that foreign influence was beginning to be felt, and a brisk trade was being carried on in reaping and pruning hooks, knives, &c., made out of hoop iron of the ordinary type imported from Europe. But the smith acknowledged with great frankness that they were only made to sell, and with many a shake of the head said that they did not last, as the metal was not to be compared with that of native manufacture.

In the face of such strong prejudice it is hardly likely that an important, interesting, and probably now unique native industry will suffer much for some time to come at the hands of European enterprise; yet the day must inevitably arrive when the native product is run off the market by the imported and machine-made article, when the hearths of this smelting village are cold, its kilns in ruins, and its workers driven to seek other employment. It is earnestly hoped that this time is still far distant, and that the peaceful, industrious community may continue for several generations to toil on in its present occupation of producing a metal which, according to the native standard, is superior to anything produced elsewhere.

Not the least important feature in this industry is the marked regularity which characterised each operation and the enthusiasm which seemed to inspire the workers. Strangely at variance with the usual custom of the Ethiopian, there was no noise, no bustle, no confusion; no sound but the hum of preoccupation was to be heard throughout the whole village. At the right moment the kiln was prepared and lighted, sealed, charged and drawn; at the right moment, when the fire was drawn, little boys stood ready with their calabash trays to take away the live charcoal, and at the right moment they brought the necessary green creepers with which to draw the pig from the cupola, or water to quench the fire. All this indicated systematic control and the strong hand of authority, and method only acquired by long practice and passed on from one generation to the next.

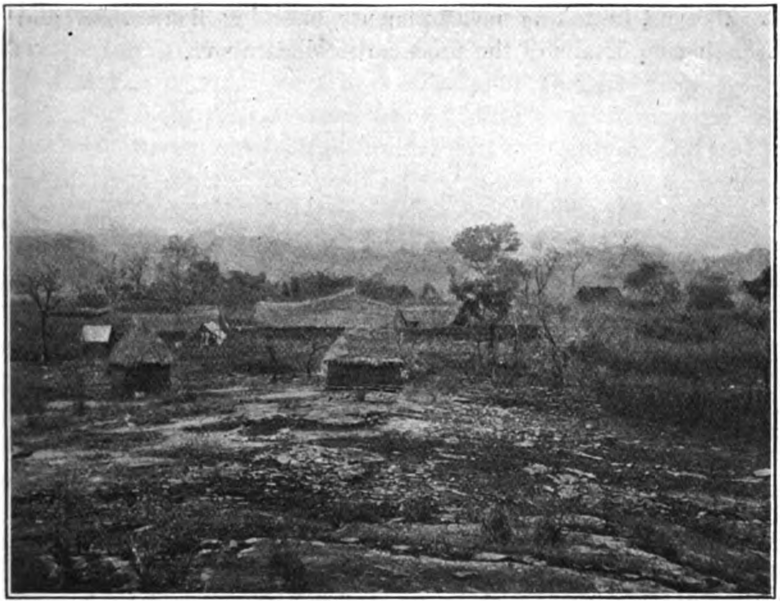


FIG. 13.—View of the Smelting Village of Ola-igbi. (The haze is due to the Harmattan prevailing at this time of year.)

Each cupola is run on the share system under a separate section of the village; there is no community of interests governing the whole village. There are none too old to work, and the young, whether male or female, commence to learn their trade as soon, apparently, as they leave the mother's breast, and are able to help in the pounding of ore as soon as they have acquired the strength necessary to lift the heavy pestle. It is a model industrial community, and may it long continue!

The writer acknowledges the assistance accorded him by Mr. J. E. Stone, in taking measurements, checking figures, &c., and in gathering details of the process described above.

APPENDIX.

ANALYSES OF SPECIMENS.

By F. W. HARBORD, Assoc.R.S.M., F.I.C.

It having been suggested that it would add to the value of Mr. Bellamy's paper if analyses of the ores and fluxes used and of the products obtained were given, I offered to make analyses of the samples sent from Lagos, and the results are appended.

It will be seen from these analyses that the ore used is a very siliceous hæmatite, containing only 36·67 per cent. of metallic iron, mostly as peroxide. By roasting, the small quantity of combined water is driven off, and the little ferrous oxide present converted into ferric oxide; and by grinding and washing, the siliceous residue is reduced from 43 per cent. to 14 per cent., and the percentage of metallic iron increased from 36·67 per cent. to 60 per cent.

The tailings contain 56 per cent. of siliceous residue and 28 per cent. of metallic iron.

The fluxes used are ferrous silicates similar to an ordinary tap cinder, except that they are more siliceous and contain less iron. The clinker ordinarily used as a flux is the last which comes away before opening the cupola, and, as will be seen from the analysis, is lower in silica and contains about the same percentage of iron as the clinker afterwards selected, thus confirming the experience of the workmen that this is the best flux; there is a very distinct difference between the best flux, or even the selected flux, and the clinker thrown to spoil, the latter being higher in silica and lower in iron.

The analysis of the smelted metal shows it to be pig iron which has been partially decarburised by the oxidising flux; it is really a puddled steel, low in sulphur and phosphorus; its purity in these respects accounting for its good qualities. The *puddling* carried out by the smith previous to forging the tool is evidently a refining similar to that carried out in a charcoal hearth, the metal being held before the blast until sufficiently decarburised. From the analyses it will be seen that the silicon was very largely removed, and the carbon reduced from 1·6 per cent. to 1·0 per cent.; and it is probable that the degree of decarburisation is varied according to the purpose for which the tool is required.

So far as the metallurgy of the process is concerned, it is similar to most direct processes, the metal being reduced by charcoal, and then partially decarburised in the same furnace by means of fusible oxides, which also largely dephosphorise the metal. It is interesting to note how complete the dephosphorisation is, as the washed ore containing 0·033 per cent. of phosphorus would, if smelted in a blast-furnace, give a pig iron with approximately 0·06 per cent. of phosphorus, but, under the conditions prevailing, of comparatively low temperature in the presence of oxidising fluxes, this is reduced to 0·01 per cent.

It is probable that the metal never collects in the fluid state on the *bottom* of the furnace; but as it is reduced and falls through the bath of oxidising flux, it is partially decarburised, its melting point raised, and the temperature is just high enough to enable it to gather together in the form of a metallic sponge, from which the fluid slag can be tapped off from time to time.

TABLE I.

Analyses of Ore Before and After Treatment.

	Ore as Mined.	Roasted Ore, before Grinding.	Roasted and Pulverised before Washing.
	Per Cent.	Per Cent.	Per Cent.
Siliceous residue	43·00	...	43·40
Peroxide of iron	48·60	53·10	53·42
Protoxide of iron	3·30	1·00	1·00
Oxide of manganese . . .	traces	...	traces
Alumina	0·20	...	0·77
Lime	0·10	...	0·10
Magnesia	traces	...	traces
Phosphoric acid	0·13	...	0·102
Sulphur	...	...	0·028
Loss on ignition (water, organic matter, carbonic acid, &c.)	4·50	...	...
Metallic iron	36·67	39·0	38·20
Phosphorus	0·057	...	0·045

TABLE II.

Analyses of Washed Ore.

	Ore Pulverised and Washed ready for Cupola.	Tailings.
	Per Cent.	Per Cent.
Siliceous residue	13·96	56·4
Peroxide of iron	85·09	...
Protoxide of iron	0·57	...
Oxide of manganese	traces	...
Alumina	0·50	...
Lime.	0·50	...
Magnesia	traces	...
Phosphoric acid	0·080	...
Sulphur	0·014	...
Metallic iron	59·90	28·5*
Phosphorus	0·033	...

* Total metallic iron.

TABLE III.

Analyses of Fluxes.

	Clinker used as a Flux.*	Selected Clinker from First Runnings from Furnace.	Dross Clinker sent to Spoil Heap.
	Per Cent.	Per Cent.	Per Cent.
Siliceous residue	38·00	49·84	52·00
Peroxide of iron	10·00	5·00	6·14
Protoxide of iron	38·43	43·65	33·68
Alumina	7·60	0·20	2·50
Lime	1·90	0·56	3·46
Magnesia	0·50	...	0·68
Phosphoric acid	0·129	...	0·180
Metallic iron	36·7	37·5	30·50
Phosphorus	0·056	...	0·081

* This is the last which comes away before the cupola is opened, and is considered the best.

TABLE IV.

Analyses of Native Metal.

	Smelted Metal broken up in a convenient Size, in which state it is sold to smiths.	Piece of Native Metal Puddled by smith at Oyo.	Chisel.
	Per Cent.	Per Cent.	Per Cent.
Carbon	1·670	1·022	1·080
Silicon	0·252	0·026	0·093
Sulphur	0·006	0·006	0·006
Phosphorus	0·010	0·012	0·018
Manganese	traces	trace	trace

DISCUSSION.

Mr. H. **Bauerman**, Honorary Member, said: This is an extremely interesting paper, because it brings before us a line of work with which we have been all entirely unfamiliar up to the present time. It is generally assumed that the making of steel was a later process than the making of wrought iron. This paper shows us very distinctly a primitive process that is really a steel-making one. The metal is not puddled steel, but a natural forged steel, high in carbon, which, by re-heating, is brought down to a one-per-cent. tool steel. This is essentially steel-making; and although we have known that in the older regions of the world, before the introduction of bellows, furnaces were worked by natural draught as shown in this paper, the author shows us that they made steel as well as wrought iron. The slags are noticeable for the low proportion of iron they contain, from 30 to 36 per cent. of iron. Any of the bloomery slags contain considerably more. He did not quite follow the paper where it stated that the yield of the metal to the crude ore is 46 per cent., and that the remaining 54 per cent. comes away in clinker. That is not a yield of 46 in 100, but 46 in 60, as the ore contains 60 per cent. of iron; that is, the loss is only 25 per cent. But that is very much less than any of the direct processes that have survived in other countries.

Sir **James Kitson**, Bart., M.P., Past-President, said: I wish to refer to a statement of the head smelter in the paper "that to the best of his knowledge there were no smelting works in this part of West Africa, and that, indeed, he had never heard of any existing anywhere else." It is quite evident that there is no Iron and Steel Institute in West Africa, and this gentleman is not affiliated to it. But it is very singular that Sir Lowthian Bell had in his possession a sketch made by Captain Grant, the great African traveller, of an iron-making plant which he discovered in the very centre of Africa. The plant was the identical one used from ages unrecorded and delineating what Grant had seen in West Africa.

Dr. **James Douglas** (New York) said: In this connection I recollect that there was in the Portuguese Colonial exhibit at the Philadelphia Exhibition of 1876 the model of a plant of this very description which had come from the Portuguese African Colonial dependencies. My impression is that, likewise at the Columbian Exhibition of 1893, there was illustrated an extremely interesting plant from one of the African possessions of Portugal. I do not know anything about primitive methods in West Africa; but the more one sees of primitive methods elsewhere, the more one is impressed with the lesson that quality of product does not always improve with increase of quantity. Whatever methods the ancients used, they were certainly very expert in practice. In Spain, near Rio Tinto, there are mountains of slags, containing hundreds of thousands of tons, made from the copper ores of those great masses of copper sulphides in Spain. And these slags are cleaner than any copper slags that we make to-day. How they were made is still more or less of a mystery. But, judging from the small size of the pieces constituting these slag mountains, one would infer that they came from the open-hearth, and not the cupola process. Copper has also been made in Spain, as in South America and elsewhere, from highly siliceous ores. It must be confessed, moreover, that the ancients made most excellent metal. And the same is true of the primitive methods for lead and tin. It is generally supposed that the old slags will yield large profits under modern re-treatment. But this is a great mistake. There are some old copper slags that are unclean; but they were doubtless produced by inexperienced beginners, or before the discovery of proper methods, and they do not represent the general character, even of the slags from sulphides. Where the ancients did not have to deal with sulphur, but smelted, in suitable mixtures, oxidised ores, they seem to have made their mixtures with much practical skill, and to have effected a very high extraction, leaving remarkably clean slags. In short, we cannot safely conclude that those old metallurgists, who worked on a small scale, and without knowledge of the chemical reactions involved in their work, were necessarily on that account inferior to us in the technical skill required for their special problems.

Professor H. M. **Howe** (New York) corroborated what Dr. Douglas said about the cleanness of the copper slags. Those ancient slags had a degree of freedom from copper which it was difficult to reproduce to-day, just as it would be difficult to reproduce the accuracy of fit of the stones of the Pyramids. How far that might be due to the gradual leaching out of the copper he could not say.

Mr. H. **Bauerman** said that as Dr. Douglas had mentioned these old copper slags, he would like to confirm what he had said. Most of those prehistoric slags, in Arabia and in the Island of Cyprus, were remarkably clean, and as clean as it was possible to make by the most careful smelting at the present time. Another curious matter in connection with the Cyprus slags was that their fluxing material was almost entirely manganese. This might be due to the ore having been cuprous manganese ore, or mixed oxidised ores with oxide of copper and brown oxide of manganese which were common in some places in the early days. It was quite possible that the Cyprian copper might have come from that source.

A vote of thanks having been given to the joint authors, Messrs. C. V. Bellamy and F. W. Harbord, the meeting adjourned until the afternoon.

On resuming, Mr. **Windsor Richards**, who occupied the chair, announced that the Council had decided that Mr. Mallmann's paper announced in the programme should not be taken at the New York meeting. The next paper was by Mr. Gledhill. He was very sorry that he was unable to be present owing to illness in his family; but Mr. Walter Carter would have pleasure in explaining the samples he had brought with him.

The following paper was then read :—

THE DEVELOPMENT AND USE OF HIGH-SPEED TOOL STEEL.

By J. M. GLEDHILL (Member of Council).

Introductory.

It would doubtless have been felt by many but a few years back that there was little left to be said on the subject of crucible tool steel, and that something akin to finality had been arrived at in its manufacture and general treatment. Probably such feeling was justifiable when it is remembered that the making of steel in crucibles is by far the oldest method known, dating back from time immemorial, it being indeed impossible to trace accurately its origin and earliest development, but it seems certain that carbon steel was made and used thousands of years ago for cutting tools. Proof of this may be seen by the marvellous carvings and workings on the intensely hard stone work of the ancients, for it would be difficult to conceive by what means, other than with steel tools, such work could have been executed, and it is wonderful to think that steel-cutting tools should have been used so long ago, whilst the principle of manufacturing them—that is, by fusion of iron and charcoal in crucibles—was then in a measure similar to that used at the present day. Archæologists have discovered that the Chinese made steel in crucibles long before the Christian era.

"Wootz" steel fabricated in India centuries ago was crucible steel, as was also the celebrated Damascus steel, produced at the forges of Toledo, and, curiously, this latter steel furnishes yet another proof that there is nothing new under the sun, for it is recorded that Damascus steel contained certain percentages of tungsten, nickel, manganese, &c., some of the very elements, in fact, contained in the present modern high-speed steel, so that a latent high-speed steel may be said to have existed centuries ago, and all that was necessary to bring out its inherent powers would have been the heating of it in a "paradoxical" manner, so to speak; that is, to such a high degree of temperature as was long thought would impair or destroy the nature of such steel. When, therefore, we look back on the period for which crucible steel has been known to the world's history, some may not unnaturally think that there has been time enough to have fully fathomed its mysteries, leaving little more to be said on the subject. It is then all the more remarkable that a discovery, which was made but a few years back, and has since revolutionised the treatment of crucible tool steel, should have remained so long a hidden secret.

A very important advance was made thirty or forty years ago, when "Mushet," or self-hardening steel, was introduced. This was the valuable invention of Robert Mushet, who, after a long series of experiments, made whilst he was manager of the Titanic Steel Co., succeeded in producing a tungsten steel, and its introduction was a great advancement on the cutting powers of ordinary crucible steel, and for many years Mushet steel held a foremost place amongst tool steels.

It is now to the United States of America, however, that all honour must be given for the next great step in having led the way in the present remarkable advancement in tool steel, and the author would like to record here that the greatest credit is due to Messrs. Taylor & White, who, at the Bethlehem Steelworks of America, initiated high-speed cutting; and at the exhibit of their firm in Paris some few years back, what were then considered to be astonishing results in speeds of cutting steel were publicly demonstrated. Since then still greater developments have been made by the author's firm in high-speed steels, and with increased experience in its manufacture, treatment, and application in our workshops, results in cutting powers far beyond expectation have been attained.

In those branches of engineering practice necessitating the use of tool steels in course of manufacture of their products, there is probably no section of greater importance than that of the application and practical use of what is now known as "high-speed steel," and it may be said without doubt that no development in the annals of metallurgy has been more striking than the production of such steel, whilst the alacrity with which users have up to now appreciated and adopted high-speed cutting steel may be said to be almost comparable with the rapid powers of the steel itself! Perhaps this is not surprising when we look back and reflect that for many years past, previous to the advent of high-speed steel, practically but little advance had been made in the cutting powers of tool steels, feeds and speeds remaining more or less in a normal condition, and it must undoubtedly have often appeared to users generally that the cutting powers of the ordinary tool steels were very slow, and that the turn-out of work could be greatly enhanced and economised if the cutting powers of tool steels could be substantially improved by some research of the metallurgist. Time has eventually realised those hopes to a large extent, and hence the desire now on all sides to use high-speed steel wherever possible. When it is seen that, with high-speed tools, steel can now be turned and machined at a rate up to 500 feet per minute, and cast iron drilled at 25 inches per minute, it must be admitted that this is an astonishing advancement on the cutting speeds of 30 to 50 feet per minute with ordinary crucible steel.

The production of steel capable of such cutting powers has not been obtained without exhaustive scientific research and trial, and the author may state that experiments have been made by him extending over a period of four years, during which time some eighty different compositions of high-speed steels were produced, and hundreds of trials made with them by actual cutting, and whilst some excellent results were obtained with many of them, others gave but indifferent ones.

In the manufacture and production of high-speed steels (the best being made by the crucible process) the author has proved conclusively that the most satisfactory results are obtained only by using the purest qualities of Swedish or Dannemora irons, which on account of their freedom from impurities are most suitable for producing tool steels that will best retain their cutting edges, and also the use of the highest qualities of the various alloys and other ingredients employed in the composition of the steel.

Special care is required in the melting and subsequent treatment of ingots alloyed with high percentages of other metals so as to ensure homogeneity and regularity of quality, which is one of the most important points to be considered, for no permanent advantage or economy can be relied on if good results are obtained from one bar of steel and inferior results from the next, as will be the case where attention and experience are not exercised.

SUMMARY OF RESULTS OF EXPERIMENTS.

The high-speed steels of the present day are combinations of iron and carbon with—

(1) Tungsten and chromium,
(2) Molybdenum and chromium,
(3) Tungsten, molybdenum and chromium.

These present many interesting varieties, and offer a wide field for research. The author has made a large number of experiments to ascertain comparative cutting powers of steels produced by varying proportions of these elements, and it may be interesting to briefly state the results of some of those investigations.

Influence of Carbon.—A number of tool steels were made with the carbon percentage varying from 0·4 per cent. to 2·2 per cent., and the method of hardening was to heat the steel to the highest possible temperature without destroying the cutting edge, and then to cool rapidly in a strong air blast. By this simple method of hardening it was found that the greatest cutting efficiency is obtained where the carbon ranges from 0·4 per cent. to 0·9 per cent., and such steels are comparatively tough. Higher percentages are not desirable because great difficulty is experienced in forging the steels, and the tools are inferior. With increasing carbon contents the steel is also very brittle, and has a tendency to break with unequal and intermittent cutting.

Influence of Chromium.—Having thus found the best carbon content to range from 0·4 per cent. to 0·9 per cent., the next experiments were made to ascertain the influence of chromium varying from 1·0 per cent. to 6·0 per cent. Steels containing a low percentage are very tough, and perform excellent work on the softer varieties of steel and cast iron, but when tried on harder materials the results obtained were not so efficient. With an increased content of chromium the nature of the steel becomes much harder, and greater cutting efficiency is obtained on hard materials. It was observed with an increase of chromium there must be a decrease in carbon to obtain the best results for such percentage of chromium.

Mention may here be made of an interesting experiment to ascertain what effect would be produced in a rapid steel by substituting vanadium for chromium. The amount of vanadium present was 2·0 per cent. The steel readily forged, worked very tough, and was hardened by heating to a white heat and cooling in an air blast. This tool when tried on medium steel stood well, but not better than the steel with the much cheaper element, chromium, in it.

Influence of Tungsten.—This important element is contained in by far the greater number of the present high-speed steels in use. A number of experiments were made with the tungsten content ranging from 9·0 per cent. to 27·0 per cent. From 9·0 per cent. to 16·0 per cent. the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased, and about 16·0 per cent. appeared to be the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18·0 per cent. and 27·0 per cent. it was found that the nature of the steel altered somewhat, and, instead of being brittle, it became softer and tougher, and whilst such tools have the property of cutting very cleanly, they do not stand up so well.

Influence of Molybdenum.—The influence of this element at the present time is under investigation, and our experiments with it have so far produced excellent results. It is found that where a large percentage of tungsten is necessary to make a good rapid steel, a considerably less percentage of molybdenum will suffice. A peculiarity of these molybdenum steels is that in order to obtain the greatest efficiency they do not require such a high temperature in hardening as do the tungsten steels, and if the temperature is increased above 1000° C. the tools are inferior, and the life shortened.

Influence of Tungsten with Molybdenum.—It was found that the presence of from 0·5 per cent. to 3·0 per cent. molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage gained is altogether out of proportion to the cost of the added molybdenum.

Influence of Silicon.—A number of rapid steels were made with silicon content varying from a trace up to 4·0 per cent. Silicon sensibly hardens such steels, and the cutting efficiency on hard materials is increased by additions up to 3·0 per cent. By increasing the silicon above 3·0 per cent., however, the cutting efficiency begins to decline. Various experiments were made with other metals as alloys, but the results obtained were not sufficiently good by comparison with the above to call for comment.

An analysis of one of the best qualities of rapid steels produced by the author's firm is as follows:—

"A. W." Steel.

Carbon . . .	0·55 per cent.
Chromium . . .	3·5 per cent.
Tungsten . . .	13·5 per cent.

What may be said to determine a high-speed steel, as compared to an ordinary tool steel, is its capability of withstanding the higher temperatures produced by the greatly increased friction between the tool and the work due to the rapid cutting. An ordinary carbon steel containing, say, 1·20 per cent. carbon when heated slightly above the critical point and rapidly cooled by quenching in water becomes intensely hard. Such a steel gradually loses this intense hardness as the temperature of friction reaches, say, 500° F. The lower the temperature is maintained the longer will be the life of the tool, so that the cutting speed is very limited. With rapid cutting steels the temperature of friction may be greatly extended, even up to 1100° F. to 1200° F., and it has been proved by experience that the higher the temperature for hardening is raised above the critical point and then rapidly cooled, the higher will be the temperature of friction that the tool can withstand before sensibly losing its hardness. The high degree of heating (almost to melting point, in fact) which is necessary for hardening high-speed steel forms an interesting study in thermal treatment and is indeed a curious paradox, quite inverting all theory and practice previously existing. In the case of hardening ordinary carbon steels very rapid cooling is absolutely necessary, but with high-speed steels the rate of cooling may take a considerably longer period, the intensity of hardness being increased with the quicker rate of cooling.

In his admirable paper on "Rapid Steel for Tools,"* Mr. Le

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* *Revue de Métallurgie*, vol. cvi. pp. 334–347.

Chatelier states that: "Steel undergoes at 700° C. a change of nature which has been studied in all its details by Mr. Osmond. This transformation, like a great number of chemical transformations, takes place with more or less considerable delay according to certain other circumstances. *When heating*, the transformation will take place above 700° C.—for example, from 750° to 800° C., according to the rapidity of heating. *When cooling*, below 700° C. the quickness with which this transformation takes place at a given temperature, is governed by a general law of chemical phenomena, and this rapidity is so much the greater (1) As the absolute temperature in question is highest; (2) As it is at its greatest distance from the point of transformation."

It may be added that the transformation at the critical point takes only a very short time in the case of simple carbon steels, and the influence of such elements as chromium, tungsten, molybdenum, vanadium, and manganese is to considerably retard this change.

Turning now to some points in the heat treatment of high-speed steel, one of the most important is the process of thoroughly annealing it after working into bars. Accurate annealing is of much value in bringing the steel into a state of molecular uniformity, thereby removing internal strains that may have arisen, due to casting and tilting, and at the same time annealing renders the steel sufficiently soft to enable it to be machined into any desired form for turning tools, milling cutters, drills, taps, screwing dies, &c.

The annealing of high-speed steel is best carried out in muffle furnaces designed for heating by radiation only, a temperature of 1400° F. being maintained from twelve to eighteen hours according to the section of the bars of steel dealt with.

Further advantage also results from careful annealing by minimising risks of cracking when the steel has to be reheated for hardening. In cases of intricately-shaped milling tools having sharp square bottom recesses, fine edges, or delicate projections, and on which unequal expansion and contraction are liable to operate suddenly, annealing has a very beneficial effect towards reducing cracking to a minimum.

Increased ductility is also imparted by annealing, and this is especially requisite in tools that have to encounter sudden shocks due to intermittent cutting, such as planing and slotting tools, or others suddenly meeting projections or irregularities on the work operated on.

The following tensile tests of "A. W." high-speed steel in the normal, annealed, hardened, and hardened and then tempered states, also the microscopic views given in Plates V., VI., and VII. of the steels in the states described, will be instructive as showing the effects of the heat treatment.

No. of Specimen.	Condition.	Elastic Limit, tons per sq. in.	Breaking Strain, tons per sq. in.	Elongation, per cent.	Contraction in Area, per cent.	Remarks.
1	Normal	...	112	...	...	...
2	Annealed	40·0	58·0	18·0 per cent.	35·0 per cent.	Fibrous
3	Hardened	..	62·0	...	...	...
4	Hardened and Tempered	...	89·0	...	...	...

The test pieces of the above are shown on the table.

It will be observed that the ductility of the annealed specimen is very good, rendering the steel in a condition to withstand the great pressures due to the forces thrown upon it when cutting.

In preparing high-speed steel ready for use the process may be divided principally into three stages: forging, hardening, and grinding. It is, of course, very desirable that high-speed steel should be capable of attaining its maximum efficiency and yet only require treatment of the simplest kind, so that an ordinarily skilled workman may easily deal with it, otherwise the preparation of tools becomes an expensive and costly matter, and materially reduces the advantages resulting from its use. Fortunately, the treatment of the rapid steel produced by the author's firm is of the simplest; simpler in fact than ordinary carbon steels or the old self-hardening steels, as great care had to be exercised in the heating of the latter steels, for if either were heated above a blood-red heat, say 1600° F., the danger of impairing their efficiency by burning was considerable; whereas with the high-speed steel, heating may be carried to a much higher temperature, even up to melting point, it being practically impossible to injure it by burning. The steel may be raised to a yellow heat for forging, say 1850° F., at which temperature it is soft and easily worked into any desired form, the forging proceeding until the temperature lowers to a good red heat, say 1500° F., when work on it should cease and the steel be reheated.

In heating a bar of high-speed steel preparatory to forging (which heating is best done in a clear coke fire) it is essential that the bar be heated thoroughly and uniformly, so as to ensure that the heat has penetrated to the centre of the bar, for if the bar be not uniformly heated, leaving the centre comparatively cold and stiff, whilst the outside is hot, the steel will not draw or spread out equally, and cracking will probably result. A wise rule in heating is to "hasten slowly."

It is not advisable to break pieces from the bar whilst cold, the effect of so doing tending to induce fine end cracks to develop, which ultimately may extend and give trouble, but the pieces should be cut off whilst the bar is hot, then be reheated as before and forged to the shape required, after which the tool should be laid in a dry place until cold.

The temperature for hardening high-speed steel varies somewhat according to the class of tool being dealt with.

When hardening turning, planing, or slotting tools, and others of similar class, the point or nose of tool only should be gradually raised to a white melting heat, though not necessarily melted, but even should the point of the tool become to a more or less extent fused or melted no harm is done. The tool should then be immediately placed in an air blast and cooled down, after which it only requires grinding and is then ready for use.

Another method of preparing the tools, which may be described, is as follows:—

Forge the tools as before, and when quite cold grind to shape on a *dry* stone or *dry* emery wheel, an operation which may be done with the tool fixed in a rest and fed against the stone or emery wheel by a screw, no harm resulting from any heat developed at this stage. The tool then requires heating to a white heat, but just short of melting, and afterwards completely cooling in the air blast. This method of first roughly grinding to shape also lends itself to cooling the tools in oil, which is specially efficient where the retention of a sharp edge is a desideratum, as in finishing tools, capstan and automatic lathe tools, brass-workers' tools, &c.

In hardening where oil cooling is used the tools should be first raised to a white heat, but without melting, and then cooled down either by air blast or in the open to a bright red heat, say 1700° F., when they should be instantly plunged into a bath of rape or whale oil, or a mixture of both.

Referring to the question of grinding tools, nothing has yet been found so good for high-speed steels as the wet sandstone, and the tools ground thereon by hand pressure, but where it is desired to use emery wheels it is better to roughly grind the tools to shape on a dry emery wheel or dry stone *before* hardening. By so doing the tools require but little grinding after hardening, and only slight frictional heating occurs, but not sufficient to draw the temper in any way, and thus their cutting efficiency is not impaired. When the tools are ground on a wet emery wheel and undue pressure is applied, the heat generated by the great friction between the tool and the emery wheel causes the steel to become hot, and water playing on the steel whilst in this heated condition tends to produce cracking.

With regard to the hardening and tempering of specially formed tools of high-speed steel, such as milling and gear cutters, twist drills, taps, screwing dies, reamers, and other tools that do not permit of being ground to shape after hardening, and where any melting or fusing of the cutting edges must be prevented, the method of hardening is as follows:—

A specially arranged muffle furnace heated either by gas or oil is employed, and consists of two chambers lined with fireclay, the gas and air entering through a series of burners at the back of the furnace, and so under control that a temperature up to 2200° F. may be steadily maintained in the lower chamber, whilst the upper chamber is kept at a much lower temperature.

Before placing the cutters in the furnace it is advisable to fill up the hole and keyways with common fireclay to protect them.

The mode of procedure is now as follows:—

The cutters are first placed upon the top of the furnace until they are warmed through, after which they are placed in the upper chamber (see Plate I.) and thoroughly and uniformly heated to a temperature of about 1500° F., or, say, a medium red heat, when they are transferred into the lower chamber and allowed to remain therein until the cutter attains the same heat as the furnace itself, viz., about 2200° F., and the cutting edges become a bright yellow heat, having an appearance of a glazed or greasy surface. The cutter should then be withdrawn whilst the edges are sharp and uninjured, and revolved before an air blast until the red heat has passed away, and then whilst the cutter is still warm—that is, *just* permitting of its being handled—it should be plunged into a bath of tallow at about 200° F. and the temperature of the tallow bath then raised to about 520° F., on the attainment of which the cutter should be immediately withdrawn and plunged in cold oil.

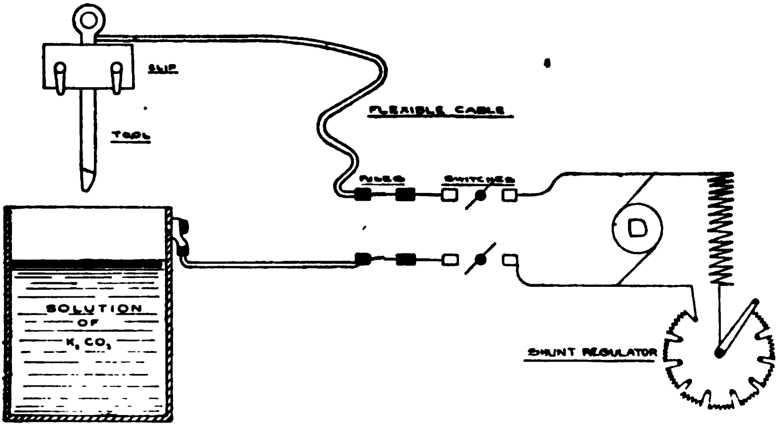


FIG. 1.

Of course there are various other ways of tempering, a good method being by means of a specially arranged gas-and-air stove into which the articles to be tempered are placed, and the stove then heated up to a temperature of from 500° F. to 600° F., when the gas is shut off and the furnace with its contents allowed to slowly cool down.

Another method of heating tools is by electrical means, and by which very regular and rapid heating is obtained, and where electric current is available, the system of electric heating is quick, reliable, and economical, and a brief description of this kind of heating may be of interest.

One method adopted of electrically heating the points of tools and the arrangement of apparatus is shown in Fig. 1. It consists of a cast-iron tank, of suitable dimensions, containing a strong solution of potassium carbonate together with a dynamo, the negative cable from which is connected to the metal clip holding the tool to be heated, whilst the positive cable is connected direct on the tank. The tool to be hardened is held in a suitable clip to ensure good contact. Proceeding to harden the tool the action is as follows:—

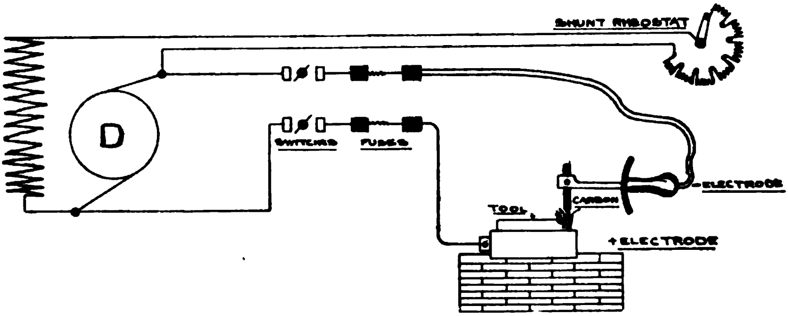
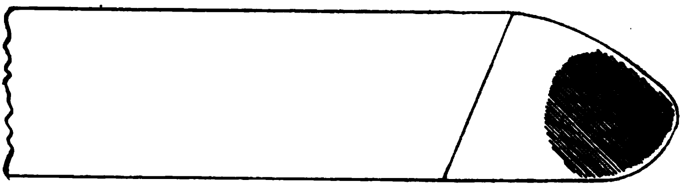


FIG. 2.—Apparatus for Hardening High-Speed Tools by means of an Electric Arc.



The Shaded Portion shows the area of Electrical Contact. The Negative Electrode should be kept moving over this Surface without approaching too near the Cutting Edge of the Tool.

The current is first switched on, and then the tool is gently lowered into the solution to such a depth as is required to harden it. The act of dipping the tool into the alkaline solution completes the electric circuit and at once sets up intense heat on the immersed part. When it is seen that the tool is sufficiently heated the current is instantly switched off, and the solution then serves to rapidly chill and harden the point of the tool, so that no air blast is necessary.

Another method of heating the point of tools is by means of the electric arc, the heating effect of which is also very rapid in its action. The general arrangement and form of the apparatus here employed are illustrated in Fig. 2.

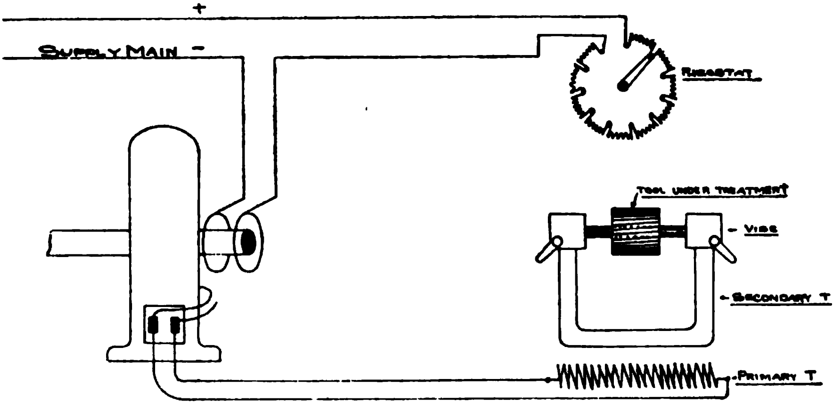


FIG. 3.—Apparatus for Tempering Milling Cutters, &c., Electrically.

The tool under treatment and the positive electrode are placed on a bed of non-conducting and non-combustible material and the arc started gradually at a low voltage and steadily increased as required, by controlling the shunt rheostat, care being taken not to obtain too great a heat and so fuse the end of the tool. The source of power in this case is a motor generator consisting of a continuous-current shunt-wound motor at 220 volts, coupled to a continuous-current shunt-wound dynamo at from 50 to 150 volts. Arcs from 10 to 1000 ampères are then easily produced and simply and safely controlled by means of the shunt rheostat.

Tempering.—Electricity is also a very efficient and accurate means of tempering such forms of tools as milling, gear, hobbing and other similar cutters, also large hollow taps, hollow reamers, and all other hollow tools made of high-speed steel, where it is required to have the outside or cutting portion hard, and the interior soft and tenacious, so as to be in the best condition to resist the great stresses put upon the tool by the resistance of the metal being cut, and which stresses tend to cause disruption of the cutter if the hardening extends too deep.

By means of the apparatus illustrated in Fig. 3 this tempering or softening of the interior can be perfectly and quickly effected, thus bringing the cutter into the best possible condition to perform rapid and heavy work.

Tempering of hollow cutters, &c., is sometimes carried out by the insertion of a heated rod within the cutter and so drawing the temper, but this is not entirely satisfactory, or scientific, as it is liable to induce cracking by too sudden heat application, and further because of the difficulty of maintaining the necessary heat and temperature required, and afterwards gradually lowering the heat until the proper degree of temper has been obtained. In electrical tempering these difficulties are overcome, as the rod is placed inside the cutter quite cold, and the electric current gradually and steadily heats up the rod until the correct temperature is reached, when it can be held at such temperature as long as is necessary, and the current can be gradually reduced until the articles operated on are cold again, and consequently the risk of cracking by too sudden expansion and contraction is reduced very greatly. The apparatus used is very simple, as will be seen by reference to the sketch. It consists of a continuous-current shunt-wound motor directly coupled to a single-phase alternating-current dynamo of the revolving field type giving 100 ampères at 350 volts, 50 cycles per second, the exciting current being taken from the works supply main.

The power from the alternator is by means of a stepdown transformer, reduced to current at a pressure of 2 volts, the secondary coil of the transformer consisting of a single turn of copper of heavy cross-section, the extremities of which are attached to heavy copper bars carrying the connecting vices holding the mandril upon which the cutter to be tempered is placed. The secondary induced current, therefore, passes through a single turn coil, through the copper bars and vices and mandril.

Although the resistance of the complete circuit is very low, still, owing to the comparatively high specific resistance of the iron mandril, the thermal effect of the current is used up in heating the mandril which gradually attains the required temperature, slowly imparting its heat to the tool under treatment until the shade of the oxide on the tool satisfies the operator.

The method adopted to regulate the heat of the mandril is by varying the excitation current of the alternator by means of the rheostat. An extremely fine variation and perfect heat control are easily possible by this arrangement.

Uses.—Having touched upon the development and thermal treatment of high-speed steel, it will now be opportune to refer to its practical use and to some of the most recent work done with it. It is sometimes contended that on the whole not much advantage or economy results from using high-speed steel, but it is easy to prove very greatly to the contrary, and the author proposes to give some figures and facts as to its use and advantage, not only by knowledge gained from results of his own firm, but also from information supplied by many important engineering establishments as to their present workshop practice and for which he is indebted.

That great economy is effected is beyond all doubt, from whichever point of view the question is looked at; for it is not only rapidity of cutting that counts, but the output of machines is correspondingly increased, so that a greater production is obtained from a given installation than was possible when cutting at low speeds with the old tool steel, and the work is naturally produced at a correspondingly lower cost, and of course it follows from this that in laying down new plant and machines the introduction and use of high-speed steel would have considerable influence in reducing expenditure on capital account.

It has also been proved that high-speed cutting is economical from a mechanical standpoint, and that a given horse-power will remove a greater quantity of metal at a high-speed than at a low speed, for although more power is naturally required to take off metal at a high than at a low speed (by reason of the increased work done) the increase of that power is by no means in proportion to the large extra amount of work done by the high-speed cutting, for the frictional and other losses do not increase in anything like the same ratio as that of a high-cutting speed to a low-cutting speed. A brief example of this may be given in which the power absorbed in the lathe was accurately measured electrically.

Cutting on hard steel, with $\frac{3}{16}$-inch depth of cut, $\frac{1}{16}$-inch feed and speed of cutting 17 feet per minute, a power of 5·16 horse-power was absorbed, and increasing the cutting speed to 42 feet per minute, the depth of cut and feed being the same, there was a saving in power of 19 per cent. for the work being done.

Another experiment with depth of cut $\frac{3}{8}$ inch and traverse $\frac{1}{16}$ inch compared with $\frac{1}{16}$-inch traverse and $\frac{3}{16}$-inch depth of cut, showed a saving in power of as much as 28 per cent., and still proceeding, with a view of increasing the weight of metal removed in a given time, the feed was doubled (other conditions being the same) and a still further saving of power resulted. In a word, as in the majority of things, so it is with rapid cutting, the more quickly work can be produced the cheaper the cost of production will be.

Again as regards economy there is not only a saving effected on the actual machine work, but since the advent of high-speed cutting it is now possible, in many instances, to produce finished articles from plain rolled bars, instead of following the old practice of first making expensive forgings and afterwards finishing them in the machine. By this practice not only is the entire cost of forging abolished, but the machining on the rolled bar can be carried out much quicker and cheaper in suitably arranged machines, quicker even than the machining of a forging can be done.

Many wonderful examples in proof of this are laid on the table, with labelled particulars of speeds and times of production from rough-rolled bars, and the saving of time is indeed remarkable. Taking the two articles illustrated below,* these were machined from plain rolled bars with high-speed steel in 45 minutes and 13 minutes respectively, as against 3¾ hours and 1¾ hours when made from forgings and using ordinary tool steel.

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* Articles Nos. 1 and 2 on page 157.

Another remarkable sample of the gain resulting from the use of high-speed cutting from rolled bars is illustrated (A, Plate II.), the articles in this case being securing bolts, made by the author's firm, for armour plates. Formerly where forgings were first made and then machined with ordinary self-hardening steel, a production of eight bolts per day of ten hours was usual. With the introduction of rapid-cutting steel, forty similar bolts from the rolled bar are now produced in the same time, thus giving an advantage of five to one in favour of quick cutting, and also in addition abolishing the cost of first rough forging the bolt to form; in fact the cost of forging one bolt alone amounted to more than the present cost of producing to required form twelve such bolts by high-speed machining. The cutting speed at which these bolts are turned is 160 feet per minute, the depth of cut and feed being respectively $\frac{3}{4}$ inch and $\frac{1}{32}$ inch, the weight of metal removed from each bolt being 62 lbs., or 2480 lbs. in a day of ten hours, the tool being only ground once during such period of work, and from such an example as this it will be at once apparent what an enormous saving in plant and costs results. On the same principle the sleeves (see appendix) for these bolts are produced from bars, sixty being made in one day of ten hours, this being even a greater saving on the old system than the bolt example shows.

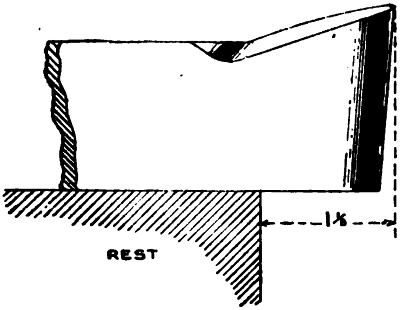


FIG. 4.

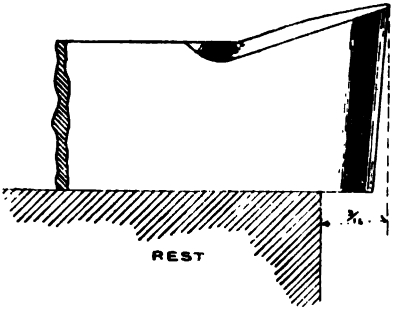


FIG. 5.

An illustration of the lathe on which this work is done is also shown (B, Plate II.). It is a 12-inch lathe of special design and strength for rapid and heavy cutting, and has a link driving belt of $7\frac{1}{2}$ inches wide, running at a very high velocity and driven by its own motor, so that the power absorbed can always be observed whether the lathe is running idle or cutting.

Equally remarkable results are obtained by operating on stock bars with high-speed milling cutters, and one example, amongst many, may be cited, which is shown (A, Plate III.). Here hexagon nuts for $3\frac{3}{8}$ inches diameter bolts are made from rolled bars, the cutting speed of milling being 150 feet per minute, giving a production of ninety nuts per day, against thirty formerly. More than ninety nuts could have been produced had the machine been more powerful.

A further economy of the great saving resulting from the use of high-speed steel was recently supplied to the author by one of the largest manufacturers of textile machinery in Lancashire. They wrote as follows:—

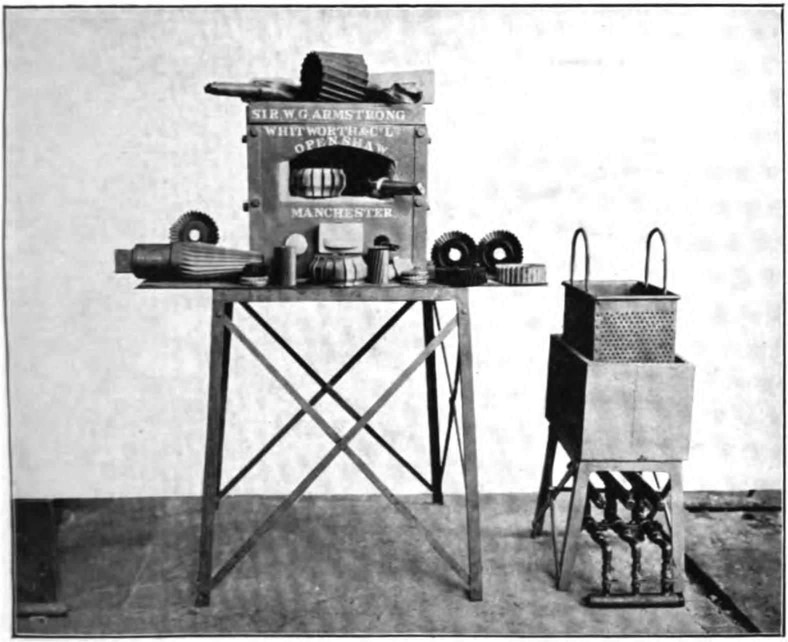
"Our results up to the present time, without being phenomenal, have demonstrated the fact that there are great possibilities for effecting considerable saving by its use, and, as examples, we would mention the following:—

"In the drilling of cast-iron rails, we have been able to increase the speed from four to eight times, and in one case of milling cast-iron brackets, we have, by building a special milling machine, and the use of the new material, increased the output six times as compared with that obtained under the old conditions.

"In another case we have been able to obtain 20 per cent. reduction in the piece-work price of the turning of some small steel articles, and we have no doubt that there are other instances, especially where we are prepared to build stronger machines, where similar and even greater savings can be effected."

One phase of milling in which cutters made from high-speed steel will play an even more important part than at the present time will be that of gear and similar cutting, it now being possible to make formed backed-off cutters of high-speed steel for all purposes, and the results obtained from the use of them, shown in the appendix, pages 152 and 162, prove beyond all doubt that very great advantage is to be gained from their application and use.

PLATE I.



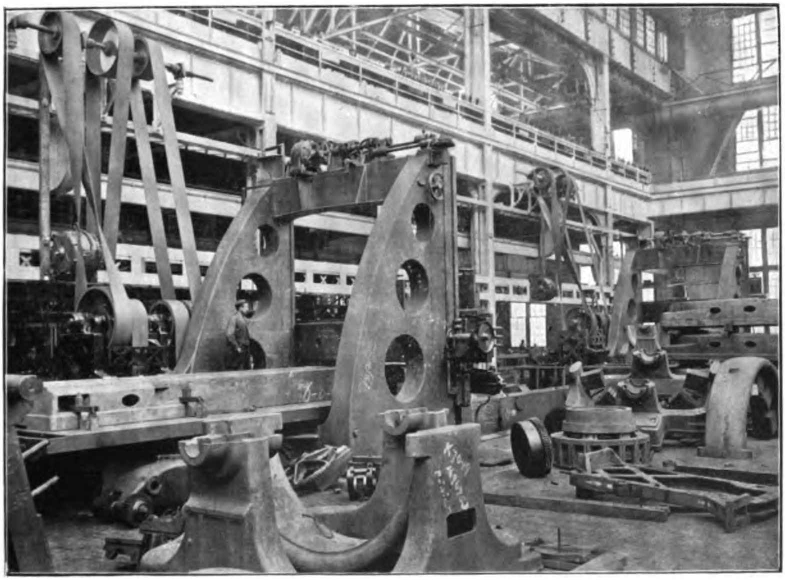
Muffle furnace for hardening milling cutters, &c., made of high-speed steel; also tank and cage for afterwards tempering them in oil. (Sir W. G. Armstrong, Whitworth & Co., Ltd., Openshaw, Manchester.)

A. Turning armour-plate bolts with "A.W." high-speed steel. One day's work of 10 hours is shown, 40 bolts being turned in that period. Cutting speed, 160 feet per minute; maximum depth of cut, ¾ inch; feed, 32 cuts per inch; weight of metal removed from each bolt, 62 lbs.; total weight removed, 2480 lbs. (Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.)

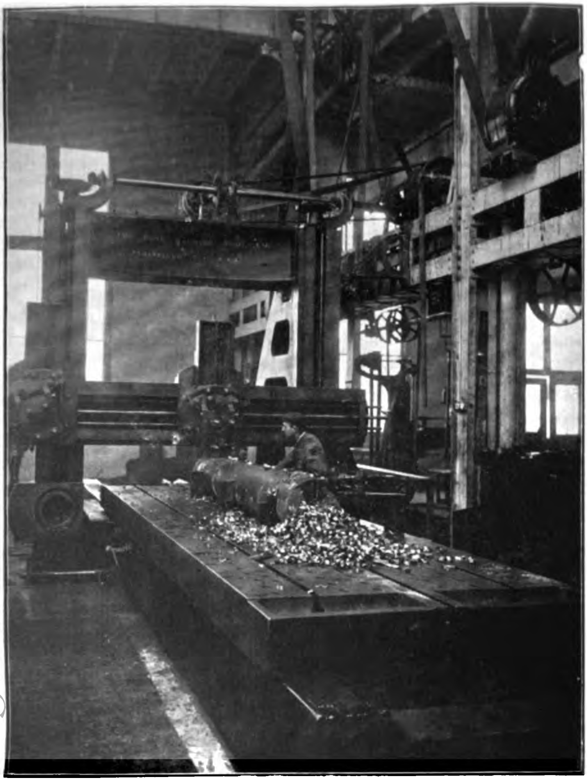
B. Turning sleeves for armour-plate bolts in 12-inch high-speed lathe. 60 bolts produced per day, of 10 hours. Cutting speed, 160 feet per minute; depth of cut, 1¼; feed, $\frac{1}{16}$; weight removed from each blank, 36 lbs.; total weight removed, 2160 lbs. (Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.)

PLATE III.

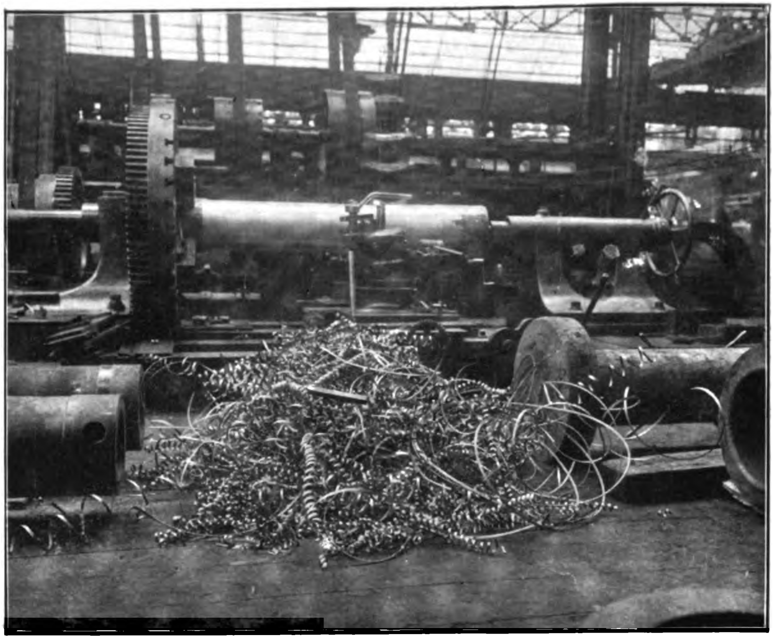
A. Making hexagon nuts from rolled bars with cutters of "A. W." high-speed steel. 90 nuts are produced in a day of 10 hours. Total weight of cuttings removed per day, 675 lbs. (Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.)



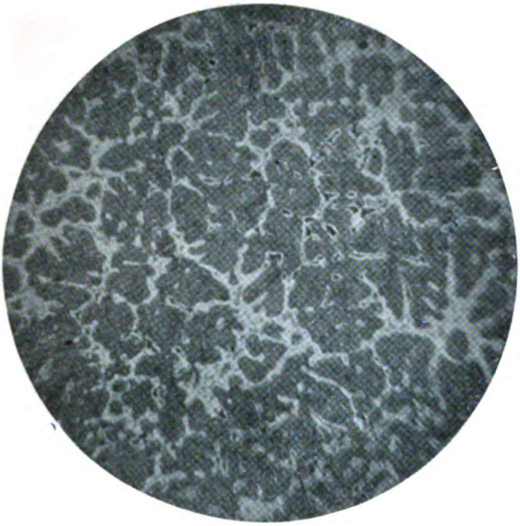
B. Planing machines fitted with Mitchell's patent drive, using "A. W." high-speed steel. Cutting speed, 36 feet per minute, returning at 80 feet per minute. (British Westinghouse Electric and Manufacturing Co., Ltd., Manchester.)



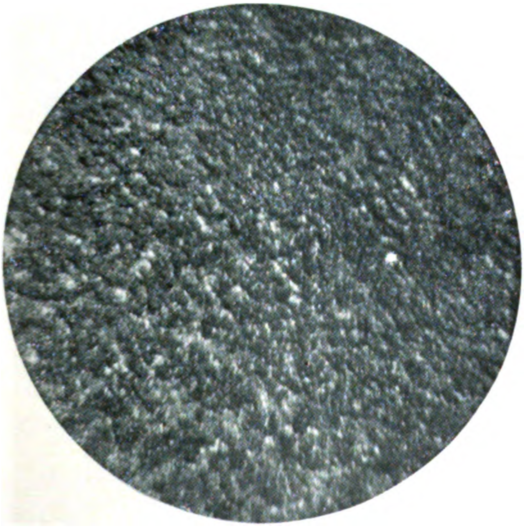
A. Planing machine fitted with Mitchell's drive, using "A. W." high-speed steel. Cutting speed, 65 feet per minute, returning 160 feet per minute; planing 145 feet carbon steel. (British Westinghouse Electric and Manufacturing Co., Ltd., Manchester.)



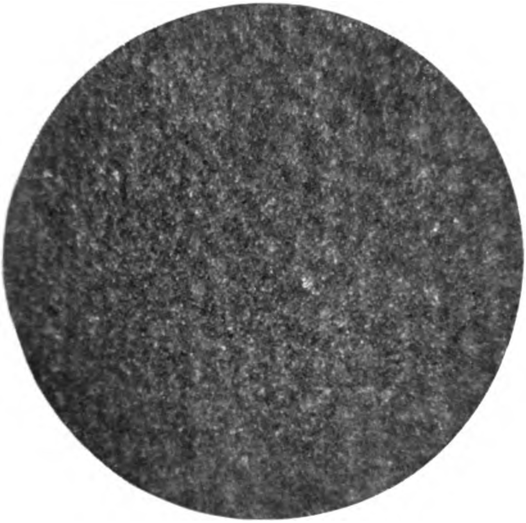
B. 45 minutes' work with "A. W." high-speed steel. Cutting speed, 150 feet per minute; depth of cut, $\frac{3}{16}$ inch; feed, 16 cuts per inch of traverse. (Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.)



As Cast.



Normal Forged.



Annealed.

Oil-hardened.

Oil-hardened and Tempered.

Again, rapid cutting with planing tools has also developed extensively, the old cutting speeds of 15 to 25 feet per minute being now replaced by those of 50 to 60 feet per minute, and in some cases even as high as 80 feet per minute, and for the same reasons, as already described in lathe turning, the power absorbed does not increase in anything like the same proportion to the extra amount of work done, so that the wear and tear on the machine is not materially increased.

It was for some time not thought possible to plane at such high speeds on account of the tools coming into contact suddenly with the job and running risks of snapping off through shock, but where high-speed steel of proper quality is used this difficulty is overcome, and a good example or two of rapid planing may be quoted. Using a 7-feet planing machine with two tools operating on forged steel of medium quality, the cutting speed, depth of cut, and feed of each tool is respectively 54 feet, $\frac{1}{4}$ inch, and $\frac{1}{8}$ inch, the speed of reverse being 160 feet per minute.

Another striking example of high speed planing on a large cast-iron turbine body was:—Cutting speed 36 feet per minute, depth of cut 1·25 inches, and feed seven cuts per inch, the tool cutting for ten hours without necessitating grinding. Two tools were cutting, each taking a cut as described, the size of the planer being 14 feet by 14 feet by 30 feet. An illustration of these machines at work is shown at B, Plate III., and A, Plate IV.

The question of cutting angles for tools is an important one, and the author would advise all interested to peruse the paper written by Professor Nicolson of Manchester, and read before the Institution of Mechanical Engineers at Chicago this year. In this he states that the best cutting angle as deduced from the results of experiments is 75° for steel and 80° for cast iron. Of course these angles may with advantage be modified according to circumstances and the nature of any particular class of work.

Objections have been made against high-speed steel on the grounds of its being brittle, but this is not the case where the steel has been properly annealed, the hardening confined to the cutting area, and sufficient support given to the tools when fixed in the machine.

An example of the great pressure-resisting powers of high-speed steel may be given.

When cutting forged steel of about 30 tons per square inch tensile strength and offering a resistance to cutting of about 100 tons per square inch, a tool of 1¼ square inch section was used, taking a cut of ⅞ inch in depth by ¼ inch feed per revolution, equivalent to an area of metal under cut of 0·21875 square inch, the cutting speed being 90 feet per minute, and removing 68¾ lbs. of metal per minute, or the huge weight of 4010 lbs. per hour. The tool in this instance was projecting a distance of 1⅛ inches beyond the rest (see Fig. 4), and a calculation shows the stress on the tool to be as high as 78·5 tons per square inch. In another case, cutting forged steel of 35 tons tensile strength and offering a resistance to cutting of 115 tons per square inch, a 1¼-inch square tool being used, the diameter of forging was reduced by 1 inch, equal to ½ inch depth of cut, whilst the tool advanced ⅜ inch every revolution, the cutting speed being 25 feet per minute and removing 14¼ lbs. of metal per minute. With the point of the tool projecting ¾ inch beyond the rest, the tool successfully withstood a stress of 51·6 tons per square inch.

Although in actual practice tools of much greater section would be used, the results clearly show that, if proper care be taken, tools of high-speed steel are quite capable of withstanding any pressure likely to be met in ordinary workshop practice.

A most important point to observe when taking heavy cuts is that of having the tools quite flat on the bottom side and supported as near as possible up to the extreme edge, as by so doing the pressures tending to break the tool are very considerably reduced. For example, the position of the tool as placed in the rest shown in Fig. 4, would cause a stress of something like 78·5 tons per square inch to be thrown on it, whereas when the overhang is reduced to one half of the original distance, equal to $\frac{9}{16}$ inch, the stress is lowered to 14·27 tons per square inch, a reduction of 80 per cent.

Perhaps one of the most unlooked-for developments in the use of high-speed steel has been the manufacture from it of twist drills, and it would be safe to say that in no other sphere has the new steel justified itself to a greater extent than in the operations of drilling and boring, as its powers in that respcet have revolutionised completely modern workshop practice. It is now possible in many cases to drill holes through stacks of thin steel plates as quickly and economically as by punching them, thus avoiding the consequent liability to distress the material due to punching action.

The plates of torpedo and other boats, which are comparatively thin and of high tensile strength, can now be drilled in stacks with such facility that it is no longer necessary to punch the holes, whilst in many articles where it was formerly the practice to core in the holes, as, for example, in cylinder and other covers, or pipe flanges, &c., it is now cheaper and quicker to use high-speed steel and drill the holes out of the solid. Many examples might be adduced in support of these statements, but reference is made to a few striking instances, full particulars of which are given in the appendix.

A short time back the author received a letter from a large firm of structural engineers in Glasgow giving some remarkable drilling results with high-speed drills, and the following extract may be quoted:—

"Drilling mild steel $2\frac{1}{2}$ inches thickness made up of five $\frac{3}{8}$-inch plates and one $\frac{5}{8}$-inch angle iron, a $\frac{15}{16}$-inch diameter twist drill made of high-speed steel, and running at 275 revolutions per minute, with a feed of 75 cuts per inch of penetration, drilled 7924 holes without requiring regrinding, each hole being drilled in 42 seconds."

As a comparison of the superiority of high-speed over ordinary drills, an instructive result was obtained when drilling forged steel gun-cradles of 5 inches thickness, this steel being of a very tough nature. An ordinary twist drill was first tried and failed after drilling 8 holes, the end being completely fused, but a high-speed drill afterwards drilled 124 holes without suffering any injury whatever. The drills were 2 inches diameter, running at 80 revolutions per minute, and each hole was drilled in six minutes, this being the full power of the machine.

A further illustration of the economy resulting from the use of high-speed twist drills may be gathered from the fact that the author's firm in several instances reduced the cost of drilling per 100 holes by over 60 per cent. without even altering the machines in any way, except by speeding them up.

On cast iron equally good results are obtained. Opening out cored holes in cast-iron girders, from $\frac{5}{8}$ inch to $\frac{15}{16}$ inch diameter, the high-speed drills do four and a half times as much work as the drills previously used, in addition to lasting considerably longer without grinding, whilst in another operation where the holes are drilled out of the solid the difference in production is eight times in favour of the high-speed drill.

Equally satisfactory results are obtained from flat drills and other forms of boring tools made of high-speed steel for use in boring large holes out of solid bars, shafts, forgings, &c., the author's firm daily using drills of this type up to 12 inches diameter and boring holes up to 50 feet long.

Other miscellaneous uses to which high-speed steel may be applied include taps, screwing dies, reamers, hot punches, circular saws, both solid and with teeth inserted in mild steel bodies, marble drilling, marble planing, rock drills, &c., also in the case of articles whose surfaces are subject to hard wear, such as lathe centres, tube expanding tools, &c.

Finishing.—A considerable amount of doubt has been thrown from time to time on the inability to take finishing cuts with high-speed steel, and in the early stages of its development this contention was to a large extent justified, but experience and practice has brought the steel into line and rendered it possible to obtain an excellent finish at high speeds with tools suitably formed and properly arranged in the machines. Some very good examples of finished bright work at high speeds are exhibited on the table and which have been mostly made in semi-automatic machines, high-speed steel being used and *one* cut only taken, and it will be seen on examination that the surface finish is most excellent.

These samples, along with many others placed on the table, also illustrate the finishing powers of high-speed steel when used in machines suitably adapted and they have been turned from the rolled bar with *one* cut only, being guaranteed accurate in diameter to 0·002 of an inch, whilst the excellence of surface finish will compare with the best obtainable by the old system of cutting, finishing, and polishing.

This finishing quality of high-speed steel is especially advantageous for tools used in automatic and capstan lathes, because it enables the work to be produced so very much more rapidly, and also on account of the great resistance of the steel to wearing action greater accuracy is ensured.

As regards the quality of retaining a sharp edge, high-speed steel makes excellent razors, and will long retain, without sharpening, an extremely keen cutting edge. The author may add that it is thus now possible to those whose time is precious to indulge even in "high-speed shaving."

The author hopes that the few facts he has given as to the use and development of high-speed steel may indicate some of its uses and progress, but he can scarcely refrain from remarking that many are saying, and rightly so, "Yes! these results are very remarkable; but what of the machines to perform such prodigious work?" and this leads him to speak before concluding as to how one important development often leads up to another of even greater magnitude, and that is in this case the complete revolution in the design of machine tools to cope with the extraordinary increased cutting powers of the latest rapid cutting steels.

It is impossible that the design of machine tools can remain on the old lines, since the difference between them and the cutting powers of the steel is so abnormal, and a sphere of immense area for the re-designing of machine tools is opened out to the ingenuity of the world's engineers.

That much has been already done is admitted, but the work is naturally of such a nature that only time and experience will accomplish, gradually enabling as nearly as possible the relative powers of the steel and machines to be equated.

In the machine tool department of the author's firm, this branch of the subject of remodelling their tools has received the closest attention, and a type of their modern 18-inch centre lathe for high-speed cutting may be mentioned. It is capable of utilising 65 horse-power equivalent to a belt width of 12 inches, and with the aid of a variable speed motor a range of cutting speeds from 16 to 400 feet per minute is possible, this comparing with an old type 18-inch lathe having a belt of 4-inch width, and capable of exerting only about 12 horse-power.

In a similar way the old types of planing, milling, drilling machines, &c., are all more or less obsolete, and new designs are already constructed to cope with work at speeds and feeds described in this paper.

It is indeed a pleasure to see the new type of machine tool operating with high-speed steel, and treating the work it has to turn out in such a business-like way, throwing off shavings from steel and iron as one usually sees in turning wood, and imparting a life and energy to the whole establishment in remarkable contrast to the sleepy rate at which metals used to be turned and machined for so many years past, thus exerting an influence on everybody therein to get "a hustle" on that is positively exhilarating in its effects.

The chemists and metallurgists with the skill they have brought to bear in assimilating the metals provided by nature to make so wonderful a product as this high-speed steel, have set a formidable task to the mechanical world, but it is satisfactory to observe that in most quarters, engineers, although for the time being in a secondary position, are roused to exercising their fullest energies in getting level. This competition can only be considered as a healthy sign, since it will give further impetus to the steel maker, and remind him to continue to fathom more and more the mysteries and powers of this steel.

In concluding this paper the author would add it cannot be denied that the question of high-speed steel is one of vast importance to all manufacturing countries, for if they are to hold their position in the world's competition they will be compelled to study the use and advantages to be derived from its adoption, and, in addition, to bring up their machinery into the most modern and efficient form for obtaining the utmost producing capacities.

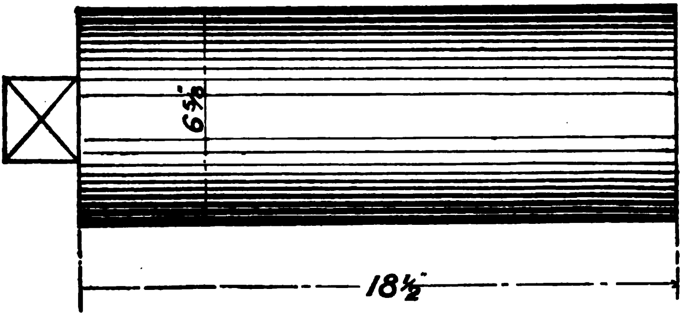
The powers of the cutting steel and the machine should be as nearly reciprocal as possible, for, given those conditions, manufacturers place themselves in the most favourable position for the rapid and economical turn out of their products, and for best meeting their rivals in the open field of competition; and lastly, notwithstanding the wonderful results obtained with the new cutting steel, and developed comparatively so rapidly, nothing approaching finality must be admitted by the steel maker, but incessant diligence, experiment, and research to discover still more the best combinations of nature's metals, should be his constant aim, and in the doing of which not only is there much pleasure derivable to himself, but in addition there is the benefit it is possible to render to the whole world.

APPENDIX

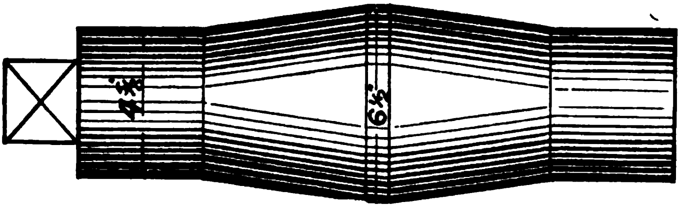
The following results with high-speed steel, the analysis of which is given on p. 132, will be of interest:—

Sir W. G. Armstrong, Whitworth, & Co., Ltd.,
Openshaw, Manchester.

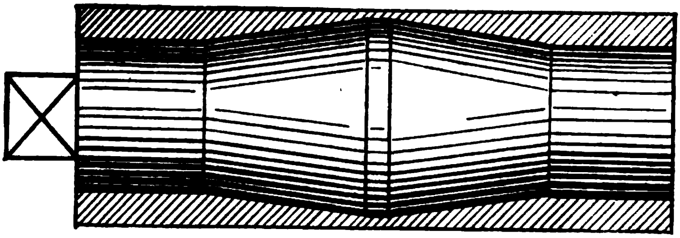
Armour Bolts.



Form of Blank from which Bolt is Produced.



Finished Bolt.

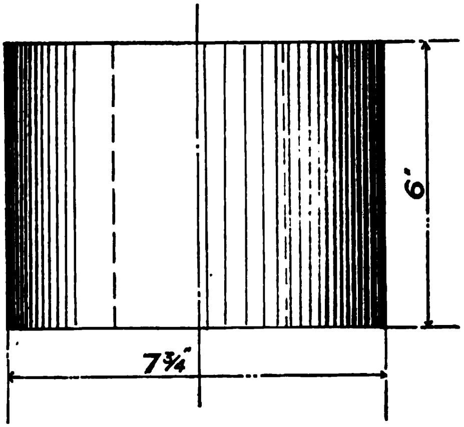


Cutting speed, 160 feet per minute. Mean depth of cut, $\frac{3}{4}$ inch. Traverse, $\frac{1}{32}$ inch. Reduction in weight, 62 lbs.

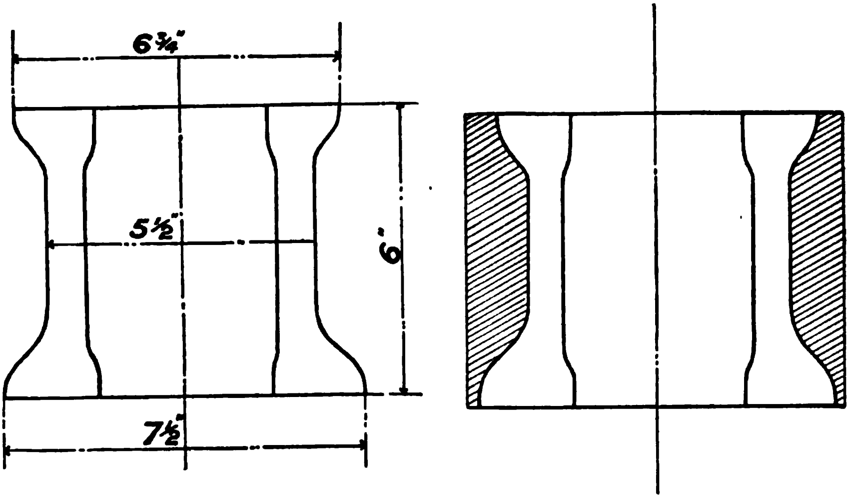
40 bolts turned in one day with "A. W." high-speed tool steel.

Sectioned area indicates the metal removed. Total weight of metal removed in 10 hours, 2480 lbs.

Sleeves for Armour-plate Bolts.



Form of Blank from which Sleeve is produced.



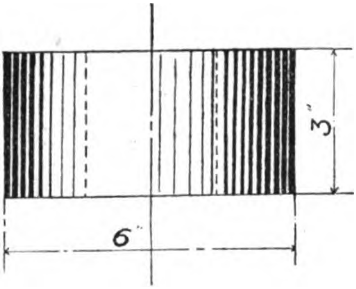
Finished Sleeve.

Cutting speed, 160 feet per minute. Maximum depth cut, $1\frac{1}{8}$ inch Traverse, $\frac{1}{32}$ inch. Reduction in weight, 36 lbs.

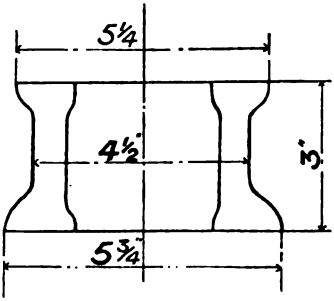
60 sleeves produced per day of 10 hours in 12-inch high-speed lathe using "A. W." steel.

Sectioned area indicates the metal removed from each blank. Total weight of metal removed in 10 hours, 2160 lbs.

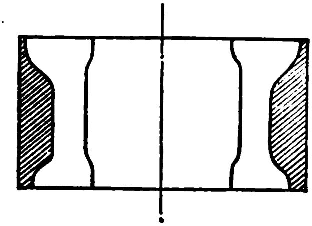
Sleeves for Armour-plate Bolts.



Form of Blank from which Sleeve is produced.



Finished Sleeve.



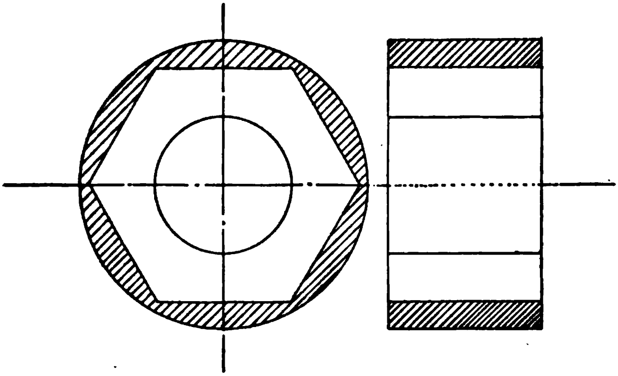
Cutting speed, 150 feet per minute. Maximum depth of cut, $\frac{3}{4}$ inch. Reduction in weight, 8·37 lbs.

90 sleeves produced per day of 10 hours with "A. W." high-speed milling cutter.

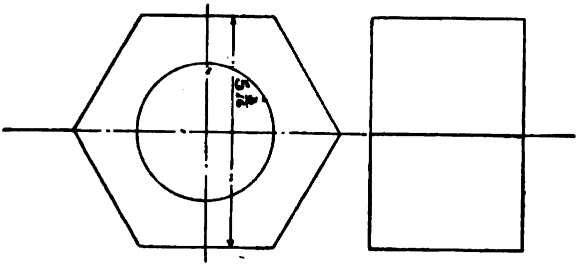
Sectioned area indicates the metal removed from each blank. Total weight of metal removed in 10 hours, 754 lbs.

Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.

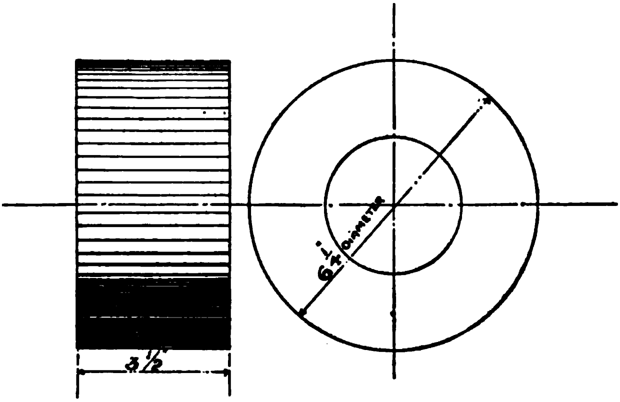
Hexagon Nuts for Armour-plate Bolts.



Form of Blank from which Hexagon Nut is produced.



Finished Nut. (Milling operation.)



Speed of cutter, 150 feet per minute. Maximum depth of cut, $\frac{17}{32}$ inch. Reduction in weight 7½ lbs. 90 sleeves produced per day of 10 hours with milling cutter made of "A. W." steel. Sectioned area indicates metal removed. Total weight of metal removed in 10 hours, 675 lbs.

A.

TESTS WITH HIGH-SPEED STEEL.

The remaining results of the latest workshop practice have been kindly supplied by various engineering firms in Great Britain, and will give some idea of the great advancement in cutting speeds since the introduction of the steel.

Turning.

The samples referred to at foot have been produced on a No. 3B hexagon turret lathe, and made from the bar direct, using high-speed steel, and upon the labels attached to the samples, details of the cutting speed, feed, &c., are given, also actual time required for machining each sample.

These samples were made, not to illustrate what is the largest amount of metal which can be removed in a given time (this regardless of finish), but what may be considered to be a fair time for producing a good job, and all the reductions on the samples were taken at one cut; no finishing cut is taken, and no filing or polishing is done.

Sample No. 1.—This is 25¼ inches long and was made from a bar slightly larger in diameter than the collar; it has seven different diameters and a screw thread, and was made in 45 minutes, and the reduction, as will be noted, is fairly large.

Sample No. 2.—This is a cone head bolt 9 inches long, and is a very good example of work indeed, and was machined from the bar in 13 minutes.

Sample No. 3.—This is 28½ inches long, and was machined from a bar slightly above the diameter of the collar in 37½ minutes.

Sample No. 4.—This is 23½ inches long, was made made from a bar ¼ inch larger in diameter than the collar; this is rather a slender job, and was machined in 21 minutes.

Sample No. 5.—This is 32¾ inches long, was made from a bar ⅛ inch larger in diameter than the collar, and was made in 33½ minutes.

Sample No. 6.—This is 27 inches long, was turned from a bar ¼ inch larger than the largest diameter, and was machined in 23 minutes 40 seconds.

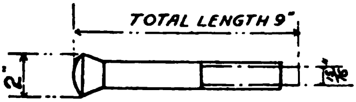
ILLUSTRATIONS OF THE SAMPLES REFERRED TO.

Finished Work Produced at High-cutting Speeds.

No. 1.

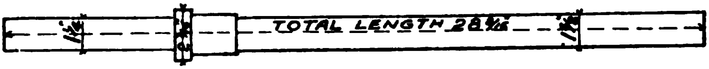
Time, 45 minutes. Cutting speed—maximum, 37·6; minimum, 12·5 feet per minute. Feed, 92 per inch; traverse, 1 inch in 1 minute 26 seconds.

No. 2.



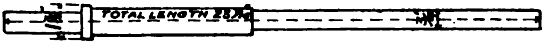
Time, 13 minutes. Cutting speed—maximum, 58·5; minimum, 27·4 feet per minute. Feed, 92 per inch; traverse, 1 inch in 49 seconds.

No. 3.



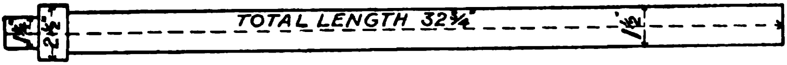
Time, 37½ minutes. Cutting speed—maximum, 49·5; minimum, 25·4 feet per minute. Feed, 92 per inch; traverse, 1 inch in 1 minute 11 seconds.

No. 4.



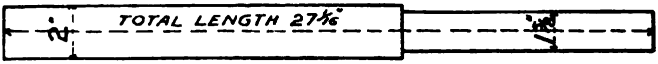
Time, 21 minutes. Cutting speed—maximum, 50·4; minimum, 27·4 feet per minute. Feed, 92 per inch; traverse, 1 inch in 39 seconds.

No. 5.



Time, 33½ minutes. Cutting speed—maximum, 41·8; minimum, 20·9 feet per minute. Feed, 62 per inch; traverse, 1 inch in 58 seconds.

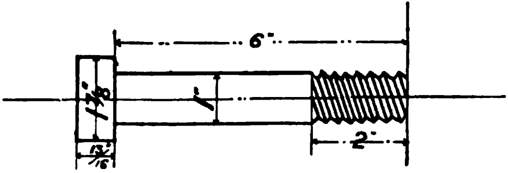
No. 6.



Time, 23 minutes 40 seconds. Cutting speed—maximum, 58·5; minimum, 47·6 feet per minute. Feed, 92 per inch; traverse, 1 inch in 49 seconds.

ILLUSTRATIONS OF ROUGH BOLTS MADE ON A NO. 2B HEXAGON TURRET LATHE AT HIGH-CUTTING SPEEDS.

Sample No. 1.



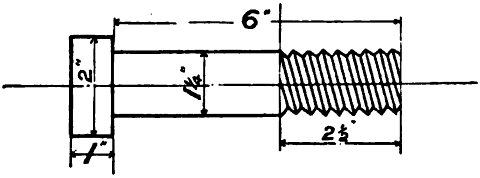
Produced upon a No. 2B hexagon turret lathe in 5 minutes 28 seconds, using high-speed tools. The following are the details:—

Reducing 1⅜ inch bar to 1 inch, 6 inches long, 96 cuts per inch	4 minutes 0 seconds.
Screwing	40 ,,
Cutting-off	28 ,,
Idle movements, &c.	20 ,,
Total . . .	5 minutes 28 seconds.

The above time does not include facing the back of the head, which would require another half minute.

This bolt, made in the ordinary way with ordinary tool steel, with a good operator, requires 15 minutes.

Sample No. 2.



This sample was made with a special tool-holder, using two high-speed tools, one at the front and one at the back, and was intended to determine what could be done in the way of producing a rough bolt quickly. The total time was 2 minutes 18 seconds, made up as follows:—

Turning speed, 144 revolutions; feed, 33 per inch	1 minute 25 seconds
Screwing	23 "
Cutting-off	30 "
Total . . .	2 minutes 18 seconds

General Shop Work.

Much of the work dealt with, especially the cast-iron work, is quite light and will not stand very heavy cuts, and up to the present it has not been possible to install special machinery for heavy cutting with high-speed steel to any great extent. It will be seen, however, that the figures given represent a very good duty on the part of the cutting steel.

Rough Turning Mild Steel Bars with high-speed steel on No. 5 hexagon turret lathe. Bars, 4½ inches diameter; turning, 31½ feet per minute; depth of cut, ¼ inch; feed, ¼ inch. The above is the result of a test. In actual practice higher cutting speeds and finer feeds are used, as the bar is not supported and will not stand these very heavy cuts when projecting very far from the chuck. The tool was lubricated with a liberal supply of lard oil.

Rough Turning Capstan Lathe Spindles with high-speed steel on 12-inch lathe. Cutting speed, 58 feet per minute; depth of cut, ⅜ inch; feed, 16 cuts per inch.

The above spindles are made of steel containing 0·5 per cent. carbon. The tool was lubricated with a liberal supply of suds. The limit of the work in this case was the lathe and not the tool. At another test the same work was done at 63 feet per minute. Cut, ⅜ inch deep; feed, 32 cuts per inch.

Boring Lathe Spindles out of the solid bar with high-speed flat cutter. The material from which these spindles are made contains 0·5 per cent. carbon. Diameter of holes, $3\frac{9}{16}$ inches. Bored out of the solid at 64 turns per minute = 60 feet per minute. Feed, 85 cuts per inch, 45 inches travel per hour.

Pulley Turning with high-speed steel tools. Roughing out, 60 feet per minute; cut, $\frac{3}{32}$ inch deep; feed, $\frac{3}{32}$ inch per revolution; finishing cut, 100 feet per minute; cut, $\frac{1}{32}$ inch deep; feed, 36 cuts per inch.

The pulleys in question are very thin, and will not stand a heavy cut.

Milling.

Milling Medium Cast Iron with face-milling cutter 4½ inches diameter, with fourteen inserted teeth made of high-speed steel, cutting at 70·7 feet per minute. Depth of cut, $\frac{5}{32}$ inch; width of cut, 3 inches; feed, 8 inches per minute.

Milling Medium Cast Iron with face-milling cutter 9 inches diameter, twelve inserted teeth made of high-speed steel, cutting at 80 feet per minute. Depth of cut, $\frac{1}{8}$ inch; width of cut, 6 inches; feed, $8\frac{1}{2}$ inches per minute.

Milling Medium Cast Iron, with face-milling cutter 12 inches diameter, with sixteen inserted teeth made of high-speed steel, cutting 75 feet per minute. Depth of cut, $\frac{5}{32}$ inch; width, 11 inches; feed, 7·5 inches per minute.

Cylindrical Cutter Milling Mild Steel.—Cutter made from high-speed steel, $2\frac{3}{4}$ inches diameter, twenty-one teeth, running at 72 feet per minute. Depth of cut, $\frac{5}{32}$ inch; width of cut, 3 inches; feed, $7\frac{1}{2}$ inches per minute.

Cylindrical Cutter Milling Mild Steel.—Cutter, 3 inches diameter, ten teeth running at 70 feet per minute. Depth of cut, $\frac{5}{32}$ inch; width, 11 inches; feed, 3 inches per minute.

Cylindrical Cutter Milling Cast Iron.—Cutter, $2\frac{1}{2}$ inches diameter—twenty-one teeth—running at 87 feet per minute. Depth of cut, $\frac{1}{16}$ inch; width $2\frac{3}{4}$ inches; feed, 26 inches per minute = 0·195 per turn = 0·0093 per tooth. With same cutter finishing cut was taken 155 turns per minute = 111 feet; depth of cut, $\frac{1}{64}$ inch; feed, $6\frac{1}{2}$ inches per minute.

Gear Cutting, 5 inches pitch. Stocking cutter, $3\frac{1}{2}$ inches diameter, cutting cast-iron spur-gear from solid. Cutting speed, 75 feet per minute; feed, 14 inches per minute.

At the time the observation was made 5000 teeth, $2\frac{1}{4}$ inches long, had been cut. The cutter appeared to be in as good condition as after cutting the first 100 teeth (thirteen and a half hours, nearly).

B.

Turning.

High-speed steel has so far been very successful on roughing 0·34 per cent. carbon steel armature shafts; the average time the tools last is about four hours. Occasionally a tool will last one day; this is owing to the variation in the steel being cut.

1. The cutting speed on this work is: 54 feet per minute; 11 revolutions per inch of feed; $\frac{1}{8}$ inch to $\frac{3}{16}$ inch depth of cut. The operator grinds his tool two or three times a day.

2. A high-speed steel tool, $1\frac{1}{4}$ inch by $2\frac{1}{2}$ inch section; depth of cut, $1\frac{1}{4}$ inches; feed, 7 cuts per inch; cutting speed, 36 feet per minute. Planed across the base of a 5500 K. W. steam turbine body; the tool worked for ten hours before requiring grinding.

3. Tool, 2 inches square high-speed steel; used in 28 feet boring mill; cutting cast-iron ring 16 feet 6 inches diameter; cutting speed, 40 feet per minute; depth of cut, 1 inch; feed, 5·3 cuts per inch; tool worked 15 hours.

4. Machine used, hexagon turret lathe; tool, roughing, $\frac{1}{2}$ inch by 1 inch section; operation, reducing a $1\frac{3}{4}$ inch rolled steel bar to $\frac{3}{4}$ inch diameter; cutting speed, 38 feet per minute; feed, 100 revolutions per 1 inch of feed. The tool lasted for over 46 hours before regrinding was required.

5. Operation, reducing cold rolled steel bars by $\frac{3}{32}$ inch in diameter; cutting speed, 160 feet per minute feed, $3\frac{3}{4}$ inches travel per minute. The tool lasted for 23 hours before requiring regrinding.

MILLING.

6. Some phenomenal results have been obtained with milling cutters on special tests; of course the work was not good enough for practical use, being furrowed like a ploughed field, but the cut was clean enough, the object being to get at the amount the cutters would stand before breaking the corners.

Slot cutter, $3\frac{1}{8}$ inches diameter, $\frac{5}{8}$ wide, 1 inch bore; 180 revolutions per minute = 147 feet; 0·050 inch per revolution = 9 inches travel per minute; $\frac{1}{4}$ inch depth of cut; material cut, mild steel. Cut for one hour in perfect condition without grinding.

With cut $\frac{1}{8}$ inch deep, the feed was put up gradually until 42 inches table travel per minute was obtained, at which feed the machine pulled up; $37\frac{3}{4}$ inches per minute was run with success. It was not considered advisable to break the corners of this cutter, after behaving so well, the cutter running for about five hours on the severest test. Although well flushed with water, the chips came off blue, and were like planer chips when broad cutting. The cutter showed very little sign of wear.

7. Slot cutter, $3\frac{1}{8}$ inches diameter, $1\frac{3}{16}$ inches wide, 1 inch bore; 120 revolutions per minute = 98 feet; 0·168 inch feed per minute = $19\frac{3}{4}$ inches travel; $\frac{1}{16}$ inch depth of cut.

Cutting cast iron, this cutter ran over 20 square feet of surface, and showed very little sign of wear when taken out.

MILLING AND GEAR CUTTING.

8. Straddle cutter, 3 inches diameter, 1 inch bore; cutting speed, 70 feet per minute; feed, 0·20 inch per revolution, $1\frac{7}{8}$ inches travel; depth of cut, $\frac{3}{4}$ inch (in one cut).

Cutting slot, $\frac{3}{4}$ inch square, in end of mild steel blocks, the cutter did 2200 pieces before requiring regrinding, lasting 80 hours.

9. Tool, steel angle cutter, 50–12; operation, milling tool steel; cutting speed, 72 feet per minute; feed, 0·03 inch, or 2·7 inches travel per minute; depth of cut, $\frac{5}{16}$ inch.

The cutter worked for three hours, and was then in such good condition that the speed was put up to 84 feet per minute, and the feed to 0·036 inch, or 3·8 inches travel per minute. The cutter then stood for $8\frac{1}{2}$ hours before it required regrinding.

Following the previous tests, trials were made with high-speed steel for cutting gears, with results as follows:—

10. *High-Speed Cutter*, 8 inches diameter, 2½ inches pitch; cutting speed, 57 feet per minute; feed, 3⅝ inches per minute; depth of cut, 0·862 inch.

Cutter lasted for three days before requiring regrinding.

Ordinary Carbon Steel Cutter, same size as above, as follows: Cutting speed, 27 feet per minute; feed, 1⅜ inch per minute; depth of cut, 0·862.

Average life of above cutter, made of ordinary carbon steel, is about three and a half hours. These cutters were used on cast steel street car motor gears, 0·50 per cent. carbon.

Gear Cutting and Drilling.

Cutting pinions, 0·34 per cent. carbon steel, for street car motors.

11. *High-Speed Cutter*, 7 inches diameter, 2½ inches pitch; 57 feet per minute; 2⅜ inches feed per minute; depth of cut, 0·862 inch.

Average time cutter lasted, without grinding, was about 27 hours.

Ordinary Carbon Steel Cutter, 7 inches diameter, 2½ inches pitch; 30 feet cutting speed per minute; 1$\frac{5}{16}$ inch feed per minute; depth of cut, 0·862 inch.

Average time cutters lasted, without grinding, was about 7 hours.

TESTS WITH HIGH-SPEED TWIST DRILLS.

12. Tool, ¾ inch drill; operation, drilling cast iron, medium hard, 4 inches thick; revolutions, 360 per minute; feed, 60 revolutions per inch of feed = 6 inches per minute.

137 holes were drilled before the drill required regrinding.

13. Tool, 1 inch drill; operation, drilling cast iron, medium hard; revolutions, 240 per minute; feed, 5 revolutions per 1 inch of feed = 4⅜ inches per minute.

78 holes were drilled before the drill required regrinding.

C.

General Shop Work.

Particulars of Work done by High-Speed Tool Steel.

Operation.	Depth of Cut.	Feed.	Cutting Speed per Minute.	Material.
	Inches.	Inches.	Feet.	
Turning . . .	1/2	1/10	40	Steel crank axles, roughing.
	3/8	1/8	50 to 70	Shaft for built-up cranks, roughing.
	1/16	1/16	120 to 140	Shafts for built-up cranks.
	1/4	1/16	60 to 70	Steel piston rods, roughing. Crosshead gudgeon pins, bolts for crank pins, &c., C.I. piston heads.
Vertical boring machine . .	1/8	1/10	50	C. I. piston rings, boring, turning, and parting off.
Inserted tools in large milling-head . . .	1/8	1/8	55	Pins of steel cranks. *Note.*—Tools are subject to impact at each revolution of the wheel. Number of tools in head, 48.
Planing . . .	1/2		25	Steel slabs for built-up cranks.
	1/2		35	Steel horn blocks, &c., also on cast iron.

The above are regular speeds and feeds, and involve about the same amount of grinding as with the Mushet steel at lower speeds. In the case of crank-pin milling, speed has been increased from 20 to 55 feet per minute.

D.

TESTS WITH HIGH-SPEED STEEL.

General Shop Work.

The following are a few rough notes relating to the performance of high-speed steel:—

1. When turning ends for large rolls with a cutting speed of 80 feet per minute on hard steel; depth of cut, $\frac{3}{8}$ inch, and a feed of 8 to the inch. In this case the tool was cutting seven hours before being reground.

2. When turning piston-rods with a cutting speed of from 110 to

120 feet per minute; depth of cut, $\frac{3}{16}$ inch; feed, 16 to the inch. In this case a heavier cut could have been taken.

3. Turning cones cut from 6-inch bore solid drawn steel tubes with a cutting speed of 160 to 180 feet per minute. By using high-speed steel the output was rather more than doubled.

4. On ordinary cast iron a speed of 80 feet per minute was attained with cuts to suit the class of work in hand, but no difficulty is found with cuts $\frac{1}{2}$ inch deep, $\frac{1}{8}$ inch feed.

5. Since adopting high-speed steel on planing machines, steel castings have been cut at 30 feet per minute instead of 17 feet as formerly.

6. High-speed steel for milling cutters has given every satisfaction. On all ordinary light work 160 to 240 feet per minute have been cut with very satisfactory results.

E.

The following is from a report relative to testing of high-speed steel:—

Test on forged crank-shaft, 22 inches diameter, was as follows:—Cutting speed, 63 feet per minute, $\frac{1}{4}$ inch feed; $\frac{1}{4}$ inch deep at this speed and feed, the tool without being reground cut for $4\frac{1}{2}$ hours; at the end of this time the tool was not punished.

Test on Cast Iron.

Turning flywheel, 16 feet diameter; cutting speed, 50 feet per minute; $\frac{1}{8}$ inch feed, depth of cut, $\frac{3}{4}$ inch.

For cast iron, such as flywheels and rope-pulleys, cylinder-covers, &c., the cutting speed on an average is from 50 to 60 feet per minute; the depth of cut and feed varying from $\frac{1}{16}$ inch to $\frac{1}{4}$ inch per revolution.

F.

TESTS WITH HIGH-SPEED STEEL.

General Shop Work.

The speeds indicated below are those of regular practice, but at the same time it may be stated that even better results than these are possible, on small shafting cutting speeds of 200 feet per minute being easily attainable.

Rough turning with high-speed steel.

Hard cast-iron rolls, 50 feet per minute, $\frac{1}{8}$ inch feed, $\frac{5}{16}$ inch deep. Roll, about 20 inches diameter by 60 inches long. A tool will turn three or four rolls without grinding.

Cast steel. 30 to 40 feet per minute; feed varying according to cut.

Mild steel. 90 feet, $\frac{1}{4}$ inch feed, $\frac{1}{4}$ inch deep.

Planing. Cast iron and steel, 36 feet per minute.

Drilling. 4 inches depth per minute up to $1\frac{1}{4}$ inches diameter, cast iron, wrought iron, or cast steel.

G.

The following is a very good example of rapid cutting on a cast-iron drum, 12 feet diameter by 5 feet face: this was turned from the black at a speed of about 35 feet per minute. The second cut was made at a speed of 50 feet per minute; depth of cut $\frac{1}{8}$ inch, with $\frac{1}{12}$ inch traverse. In this instance the tool completed the entire surface of the drum without once regrinding, and was in excellent condition at the termination of the work. Two similar cuts have also been done over a drum of exactly the same diameter as above with the same tool, without regrinding from start to finish, at a speed of 50 feet per minute and without losing $\frac{1}{64}$ inch in girth on the drum during the operation (twenty-seven and a quarter hours' cutting).

H.

A few examples of the results of work with high-speed steel and drills are herewith submitted, the same being results of daily usage and not test results. Much higher average results could be obtained were the belt powers of the lathes and drilling-machines not rather limited.

Turning.—Roughing mild steel bars of $3\frac{3}{8}$ inches diameter for worm shafts. Maximum speed, 150 feet per minute; minimum speed, 70 feet per minute; depth of cut, $\frac{3}{16}$ inch; feed, 5 inches travel per minute; tool works 7 to 8 hours without grinding.

Facing Cast Iron.—Speed, 75 feet per minute; depth of cut, $\frac{1}{8}$ inch; feed, $\frac{1}{16}$ inch.

Turning Hard Cast-Iron Ram.—Speed, 45 feet per minute; depth of the cut, $\frac{3}{16}$ inch; feed, $\frac{1}{16}$ inch.

Planing.—Speed, 34 feet per minute; depth of cut, $\frac{3}{8}$ to $\frac{1}{2}$ inch; feed, $\frac{1}{32}$ inch; tool works 6 hours without grinding.

Drilling with High-speed Twist Drills.—$\frac{3}{4}$ inch drill, drilling cast iron and mild steel; speed, 200 revolutions per minute; feed, $1\frac{5}{8}$ inch per minute.

Ordinary Twist Drills will not stand at the speed at which high-speed drills are run, and are destroyed immediately, the practice being to run ordinary drills two speeds slower than high-speed drills.

I.—TESTS WITH HIGH-SPEED STEEL.

Drilling.

A high-speed twist drill $\frac{15}{16}$ inch diameter used for drilling steel girders consisting of $5 - \frac{3}{8}$ inch plates and one $\frac{5}{8}$ inch angle iron $=$ $2\frac{1}{2}$ inches thickness in middle of girders and 1 inch at ends, drilled 7924 holes before sharpening, and in the case of another similar drill 6504 holes were drilled before sharpening, the drills running 275 revolutions per minute with a feed of 75 cuts per inch, equal to a feed of 3·6 inches per minute. Formerly when using ordinary twist drills of $\frac{3}{4}$ inch and $\frac{7}{8}$ inch diameter the speed ranged from 96 to 115 revolutions per minute, and feeding about $\frac{5}{8}$ inch to 1 inch per minute. These figures speak for themselves, the life of the ordinary drills formerly used being well known to most engineering firms.

Roll Turning.

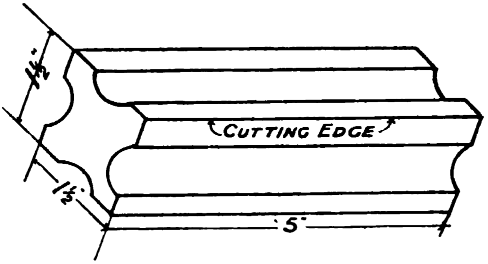


Fig. 9.—Shape of Steeling used.

As is generally known, the surfaces of chilled cast-iron rolls are so extremely hard that, in turning them, only the very best steel is of any use, and the cutting speed must be exceedingly slow.

Moreover, in turning large plain chilled rolls, sharp or narrow-pointed tools, such as are used on general traversing lathe work, would not stand at all, the form found to answer best being as shown on sketch above. These tools are wedged against the barrel of the rolls thus :—

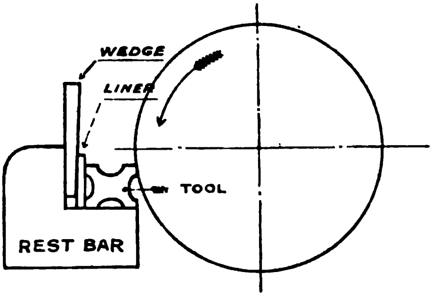


Fig. 10.—Methods of using Steeling.

Hitherto the circumferential cutting speed generally adopted has been about 6 feet per minute, and the reduction of the metal very small, as will be seen by examining the sample box of turnings marked (A), which were cut off at the speed referred to with a tool of the best usual quality of steel. With this tool, if the cutting speed was increased, or a heavier cut put on, the edge of the tool would promptly fail. By using high-speed steel it was found practicable:—

1. To increase the cutting speed from 6 feet per minute to 11 feet per minute.

2. To put on a much heavier cut, as will be seen by comparing the sample turnings (B) with the lighter sample (A), cut with the best usual steel.

3. In addition to the above advantages of quicker work and heavier cutting, the special tool referred to will last much longer without taking out for self-cooling or grinding.

DISCUSSION.

Mr. E. **Windsor Richards**, Past-President, said that at a recent meeting of the Institution of Mechanical Engineers a paper was read on tool steel, and he called the attention of the members to the high-speed tool steel at the Bethlehem Works. They would have the pleasure of seeing those wonderful works and would see 60, 70, 80, and 100 tons on lathe with half-a-dozen of these high-speed tools running.

Professor H. M. **Howe** (Columbia University) said that they all looked upon these high-speed tool steels as of very great importance, particularly to the machine shop. One point occurred to him: Had it really been shown that Swedish steel is necessary, or better than equally pure steel that is not Swedish; and is cemented steel really necessary, and is there any advantage in using that rather than equally pure open-hearth steel? It might be well if the author could indicate the kind of evidence on which he bases his assertion that it is necessary to have cemented Swedish steel. Many were hoping for the development of high-speed steels from elements which exist in great quantities, such as silicon, manganese, and chromium, rather than from rarer metals like molybdenum, vanadium, and tungsten, the supply of which is likely to be soon exhausted. If the high cutting speed was to last more than a generation, it seemed to him that they would have to draw upon the common elements and not upon the rare ones.

Mr. **Tom Westgarth** (Middlesbrough) said he fully appreciated what had been said about the advantages of using high-speed steel, because great benefit had been derived from the invention in the works of his firm, and he desired to give his thanks to the American engineers who commenced the investigations which led to the discovery and use of high-speed tool steels. While he agreed with the very great advantages arising from the use of high-speed steels, he thought the author of the paper had, no doubt unwittingly, overlooked the fact that part of the credit was due to the improved machines which had concurrently come into use. When his firm commenced using high-speed tool steel it was very soon found that the capacity of machines built to ordinary designs was reached, and therefore it became necessary to get new tools or alter and strengthen existing machines, and thus a means was obtained for using the special tool steel to every advantage and the output was greatly increased. He therefore thought some of the credit must be given to the new and altered machinery. He observed on the table some samples of work labelled with the time occupied when using new and old steel, and he thought the comparisons were a little misleading, because the whole of the time saved was not due only to the use of steel but of special machines, and besides, he thought some of the times given for the old kind of tool steel were unduly long. An interesting development occurred in his firm's works when it recently became necessary to build a new smith's shop. It was found that although their trade was increasing a smaller smith's shop could be used, because of the increasing amount of work done in special machines and by the use of high-speed steels. In connection with using high-speed steel an interesting discovery was made by one of his workmen, who found that when roughing forgings and iron or steel castings he could obtain a considerably better result by first painting the work over with a chalk mixture such as that used for marking off.

Mr. H. H. **Campbell** (Steelton, Pa.) said the point raised by Professor Howe that Dannemora iron was necessary should be carefully considered before it was finally recorded, for it involved the question whether it was necessary in the manufacture of any tool steel to have Swedish iron in order to produce the best results. The traditions of the past should not be accepted as conclusive if there is any way of testing the matter. His own company made these special steels, and while they did not think they made them better than anybody else in the world, they believed they had made as good a product as several other makers, although they did not use Swedish stock of any kind. It would be interesting to have proof that Swedish iron was necessary, and important to know the reason why.

Dr. **John A. Mathews** (Syracuse) said: It has been the experience of the company which I serve that Swedish iron is not necessary. We get equally good results using Swedish or a great many of our domestic irons which in analysis are as good or better than Swedish iron. Sulphur 0·007 and phosphorus below 0·01 are not unusual in American irons. The tendency in regard to high-speed steels has been to force one grade of high-speed steel into use for all grades of work. We shall have to differentiate a little when we come to a better knowledge of alloy steels. We undertake in the case of carbon steels to select the steel according to the use to which the steel is to be put, and we shall soon have to do the same with high-speed steel. There are a great many alloy steels that will do remarkable work, but they cannot be produced economically or commercially. We must strike an average between what we can make economically and what can be used to best advantage. We have used some hundreds of tons of molybdenum, and could supply the data Mr. Gledhill's paper lacks concerning this metal. I think that it is equal to tungsten when properly handled. We have probably made as many or more trials than Mr. Gledhill in all sorts of combinations of tungsten, molybdenum, and chromium, and the conclusions that Mr. Gledhill has put before us are practically confirmed by our own experience. We appreciate very highly that he should give us such information, for there are not many manufacturers who would put this before the public.

Mr. **A. S. Pye-Smith** (Sheffield) said: Being one of those who are at present engaged in the manufacture of the original Mushet steel, I have naturally taken considerable interest in this paper upon high-speed steel. I do not know, however, that I have much to add to what has been said. The paper is extremely interesting, and I think the makers of high-speed steel will be grateful to Mr. Gledhill for giving so much information to the users as to its proper use and treatment. The maltreatment of good steel by the users is one of the great troubles the steel-maker has. He has it with the old crucible steel still, but I think this paper will considerably help those who use high-speed steel to treat it properly. There is one point I should like to speak of, viz., that this steel being so hard and brittle, it is very important to avoid sharp corners or angles as far as possible in making tools of it. Further, many tool-makers stamp on their tools some letter or other mark, sometimes stamping them rather deeply. These marks should not be put on parts of the tool that bear any strain, as they form the starting place for fractures just like a diamond scratch on a piece of glass. I have seen several tools broken across where they were stamped just in this way. With reference to the influence of the various elements, Mr. Gledhill has not made any mention of the influence of manganese on high-speed steel. Mr. Metcalf, in his "Manual for Steel Users," lays great stress upon the importance of manganese as the hardening element in self-hardening steels. I should like to know whether Mr. Gledhill has carried out any experiments to ascertain whether manganese is detrimental to or improves high-speed steel. With regard to molybdenum, my experience seems to be the same as that of Dr. Matthews, namely, that manufacturers have used molybdenum on this side of the Atlantic much more than on the other. As to the use of the purest qualities of Swedish or Dannemora irons, I recently saw it stated in *Engineering*, under the trade report from Sheffield, that, as the best Swedish irons did not enter into the composition of high-speed steel, the trade in those brands was not very brisk.

Professor J. W. **Richards** (Bethlehem, U.S.A.) said: The electrical heating of the tool is an adaptation of the well-known Burton water-pail forge. The current sets free hydrogen, and the arc jumping across the sheath of gas causes local heating. The mention of the use of molybdenum brings to my mind the difference between the practice in Europe and America. On looking over that very fine work on steel recently written by Mr. Harbord, the word molybdenum is not to be found in the book, and the statement just made by Dr. Mathews that several hundred tons of molybdenum have been used in America, would tend to show the differences in the practice in the two countries. Mr. Pye-Smith says that high-speed tool steel is very hard and brittle; and in Mr. Gledhill's paper the influence of the carbon in increasing brittleness is emphasised, it being pointed out that from 0·4 per cent. to 0·9 per cent. is the most advantageous quantity of carbon to be used if brittleness is to be avoided. The particular advantage of using molybdenum is that it gives all the desirable quantities of high-speed steel, with carbon kept below 1 per cent. So that the desirable qualities are obtained by the use of molybdenum and quite low carbon, thus avoiding the hardness and brittleness caused by the higher carbon used in high-speed steels having no molybdenum—the ordinary high-speed tungsten steels.

Mr. OBERLIN SMITH (Bridgetown, N.J.) said: I am very much interested in these steels and I have made experiments with them. There is no doubt that the steel-makers have opened an entirely new era which will bring in more improvements. I am not a steel-maker, nor a chemist, but I am interested in the mechanical side. I am using a new shop which has nothing in it but high-speed. The change in machine tools is going to do more than we think or realise at present. With such tools as lathes and milling-machines we should not see much change without an enormous increase in strength. We have to avoid the vibration owing to the higher speed. I do not think that we want heavier spindles, but heavier beds to give more stiffness than we have been used to. Now, other tools of the reciprocating class are destined to be revolutionised, especially planing tools. We can increase the speed of rotative tools to any amount. But in the use of the reciprocating tools, the inertia soon imposes a limit. We cannot use these high-speed tools in certain cases. In spite of all that we can do we cannot get up to from 100 to 200 feet per minute. Therefore one of the great changes that will come over us in a very few years will be with planers, moving tools on stationary tables and works. This is one of the revolutions that is bound to come in machines. Another one is to abolish planers altogether. In my opinion the development of the milling-machine has only just begun, and there are going to be wonderful strides in substituting it for the planer. We shall not only get the much higher speed that is possible with using these high-speed tools, but we will get more work and have fewer strains. We have the advantage, too, of some of those rotating tools which pass round. I find in equipping a whole shopful of tools that, with the changes due to both the high-speed steels and all the conditions necessary to motor driving, very interesting problems arise. It will certainly require great ingenuity on the part of the high-speed tool-makers.

Mr. W. Carter (Manchester), replying in the absence of Mr. Gledhill, said: Mr. Westgarth says that the high-speed steel has condemned many of the existing machine tools, and only by building special machines is it possible to get the best out of the high-speed steels. This is quite true as far as my experience leads me. But still I wish to say that I have proved that high-speed steel is economical even when applied to the oldest machines that are usually found in most workshops. All our planing machines that were formerly cutting at 18 to 24 feet per minute are now cutting at 35 to 40 feet, and that has been obtained by merely putting a larger drum on the line shaft. Considering that the cost of a tool would be, say, 7s., it would not be necessary to work very long at the increased speeds to pay for the high-speed tool. The orders are that all machines are to be equipped throughout with high-speed steel, it having been proved that it is profitable to do so. I do not think you could have a stronger advocate for building special tools than Mr. Gledhill. You will find that he makes a special point of it, and in the Openshaw Works are installed some of the most powerful machines yet built for rapid cutting. Mr. Westgarth's remark about the smaller smith's shop bears out the author's statement that the introduction of high-speed steel must have a great effect upon reducing the expenditure on capital account. Referring to the samples, I may say that the intention was to get a comparison between an absolutely modern method as against a method that was in vogue previous to three years ago, and that the times as stated are absolutely the net times. The two articles were made by competent operators using ordinary tool steel, and the times given include the centreing and the necessary stretching. The times are right to the minute. Dr. Mathews of the Crucible Steel Company of America, I understood to say, was not satisfied that one brand of steel was capable of universal application. Perhaps that was not so, but so far as we have gone at present it is found that for most purposes, with all its defects, the high-speed steel wherever applied beats out of service ordinary steel. Whether that will remain so as the high-speed steel is further developed it is not very easy to say; but at the present time that is generally found to be the case. Mr. Pye-Smith made some interesting remarks, and I can fully bear out what he said about the sharp corners and deep stamping. As one travels round one meets some users of high-speed steel who seem to wish to bring about its death, and they put it to tests that they would not dream of putting ordinary tool steel to, and if it breaks they say that the high-speed steel is no use. I may say that some months ago we tried an experiment to prove whether high-speed steel would stand the loads that would be met with in ordinary workshop practice, and for that purpose a tool 1¼ inch square was used. It was used in a 40-inch lathe and we took a cutting with that tool ½-inch deep, and ⅜ feed. Since the load on the tool is independent of the speed, the speed does not matter, but we got the maximum power obtainable from the lathe, which gave a speed of about 25 feet per minute. The cuttings are at the end of the room, and they prove without any doubt at all that if high-speed steel is applied with reason and common sense it will not fail to give satisfaction. Mr. Oberlin Smith thought the machines ought to be heavier and more rigid. We are making them so. But I cannot see eye to eye with him in regard to the planing machines. I have seen a 7-foot planing machine running at 65 feet per minute and returning at 160 feet taking a cut ½-inch deep by ⅛ feed. Now cutting at 65 feet with the feed mentioned will try the best of high-speed steels. The work since speeding up to 65 feet has been produced at 40 per cent. of the price previously paid. In my general experience in machining articles of short length, milling is usually quicker owing to the time spent in reversal of the planing machines being such a large portion of the total time taken. But where the articles are of any length the planing machine is found to be a long way ahead of any milling machine yet built. I could give the names of many firms who are using both systems. Concerning the question of a planing machine having moving tools, it will be interesting to state that many such machines are at work at Openshaw. In fact the whole of the armour-plate planing machines are built on those lines and we have as many as sixteen tools cutting at one time. The tools are fixed in separate tool-boxes mounted upon the cross slide which is carried by two uprights which receive the motion from two driving screws. The plates do not move at all, and the machines are constructed to cut both ways. I do not know whether machines of similar design have been constructed for light work, but machines, as described, have been built, for heavy work, for some years past.

CORRESPONDENCE.

Dr. H. C. H. **Carpenter** (Teddington) wrote that Mr. Gledhill was to be congratulated on the publication of so valuable a paper. As the manufacture and heat treatment of such steels are still in the experimental stage, it might be of interest to state that for the past eight months he (Dr. Carpenter) had been engaged in his capacity as a Carnegie Research Scholar in investigating their behaviour under varying thermal treatment, and proposed to submit the results of his experiments to the Institute in due course.

Mr. **John Little** (Sheffield) said it appeared to him that relatively far too much importance was placed on the feed and speeds at which high-speed steel would work, and not nearly sufficient attention was given to the question of the economy obtained by greater durability. As one of his firm's representatives once remarked, a great difficulty in selling high-speed steel was owing to the name of "high speed." In many cases engineers only seemed to think of this one aspect, and they often pointed out that theirs was special work, with perhaps a machine working only 25 per cent. of its time, the remainder of the time being occupied in setting, &c., and that, therefore, if the work were done twice as quickly it would only save them a comparatively very small amount, and they therefore failed to see the advantages of the extra expenditure. This really was not the question. The economy arises: (1) Because a man does not have to take his drill or milling cutter out of the machine to be ground, so that he saves some of the time the machine would otherwise be standing; (2) because the drill, being more durable, does not wear small in diameter, and consequently does more accurate work, as it continues to fit the bushed hole in the jig; (3) because the fewer times that a drill is ground the longer must be the life, as grinding of course shortens the drill each time. As practical illustrations of the foregoing, he stated that in one department in his firm they manufactured a large number of milling cutters. A certain customer was in the habit of placing a large order every January at a time when they were supplying milling cutters of ordinary steel. At last they persuaded the firm to use their 0172 High-Speed Steel. The usual order did not come the following January, and their representative went to inquire about it. He was taken into the stores and shown more than half of the cutters which had not even been used, as the others had lasted so much longer. The firm informed him that they did not expect to order again till the following January, and next year they would not order more than half the quantity, as one year's supply was sufficient stock. So far he had only dealt with initial cost; there was also the saving in grinding and the time the machine was not occupied, men's time going backwards and forwards, use of grinder, &c. He would give them another example: A large firm who used their goods made a rule that the men were not to grind their own tools, and kept a special department for that purpose. This department consisted of seven men. They adopted high-speed steel throughout, and now that department consisted of two men, who could easily cope with all the work. Again, a firm of factors who handled his firm's goods made a calculation when they started as to the number of drills they had been in the habit of selling. When they had high-speed drills they found the demand as regards the number of drills was less than half on account of the extra durability. It was not too much to say that the extra price of high-speed steel was saved on the cost of emery wheels alone.

Mr. F. M. Osborn (Sheffield) pointed out that while Mr. Gledhill had referred to the discovery of self-hardening steel by Robert Forester Mushet, Bessemer Gold Medallist of the Iron and Steel Institute, he had made no mention of the influence of manganese in high-speed steel. The importance of manganese as a constituent of steel seems to have influenced Mr. Mushet in his experiments. While he was experimenting in 1868, not with a view to producing a cutting steel, but an entirely different object, he found that one of his trial bars had the property of becoming hard after being heated, without the hitherto necessary water quenching. The element which gave the steel this property was tungsten. Mr. Hadfield fully explained the influence of this element in his recent contribution. In 1871 the Mushet process of making steel was taken up at the Clyde Steel Works, Sheffield, under the direction of Mr. R. F. Mushet and his two sons, and since then has been introduced into every engineering workshop in the world. Mushet steel was generally called self-hardening; but it was discovered by several engineers independently, of whom it is believed the late Mr. Henry Gladwin was the earliest, that a much better result was obtainable if the cutting portion be reheated and cooled in an air-blast. Tools which had been laid on the ground and cooled by the draught of air from under a door led to this discovery. It was then proved that tools which were reheated to a full scaling, or almost yellow heat, did better work. It was difficult, however, to get the smiths to do this, and in the days before the introduction of high-speed steels, principals and managers took little interest in the heat treatment and work of cutting tools. The following, which appeared in the September issue of the *Iron and Steel Magazine*, was of interest in this connection:—

"In a paper on 'Alloy Steels' read by Mr. William Metcalf he draws a sharp distinction between ordinary self-hardening or Mushet steel and those special steels now known as high-speed steels. 'The present high-speed steels,' the author writes, 'are in no sense of the word air-hardening.' And we find this opinion shared by other metallurgists and engineers. To us it seems, however, that no such distinction can be made between these two varieties of steels. Mr. Metcalf himself says that the discovery of high-speed steel resulted from the overheating (possibly accidental) of some ordinary self-hardening steel. This treatment, which had hitherto been considered ruinous when applied to self-hardening steel, resulted in imparting to it those wonderful high-speed qualities now so well known. By this treatment the self-hardening steel was converted into high-speed steel. We want no more conclusive evidence of the fact that no sharp demarcation can be drawn between self-hardening and high-speed steel. It may be that, as at present manufactured, the high-speed steel differs materially in composition from Mushet self-hardening steel. It may be that the proportion of tungsten has been increased and that of manganese lowered, or that in some brands the tungsten has been replaced by molybdenum. The fact remains, nevertheless, that, to all tungsten steels of the self-hardening variety, if properly treated, high-speed qualities may be imparted. By altering the composition, as pointed out, these high-speed qualities may be intensified, but the difference between the two varieties of steels remains at best one of degree, not of kind."

This is exactly the case regarding the steels manufactured by the writer's firm, viz., R. Mushet's Special Steel (the original self-hardening), commonly called "Mushet Steel," and Mushet High-Speed Steel. The latter is made on the same principles, and its present form is the result of some two hundred different trial mixtures, and hundreds of lathe trials cutting various metals. The hardening is best done by reheating tools after they have been allowed to cool naturally. It is necessary to practically burn the nose end, and the liberal grinding generally recommended is to remove the outer burnt crust. The writer wishes to confirm Mr. Gledhill's advice that a wet sandstone is the best, and that if an emery wheel be used it should be before the hardening operation. A number of experiments have been made at Clyde Works with oil and hot water as cooling mediums, but it has been found that compressed air at about 60 lbs. pressure gives the best all-round results, though hot water may be advantageously used when hard materials are to be cut. It is a good plan for the smith to leave bent tools in his hearth and allow them to soak well through during the night, in order to anneal and take out the forging strains. In the morning the heat-hardening operation should be given to the cutting points only. The smith's hearth is used for the test tools at Clyde Works, and has been found the best all-round method. For general work it cannot be beaten, if it is worked by an intelligent man. The hearth must be supplemented by an arrangement for air-cooling connected with the blast pipe. The American gas furnace, which is useful for cast-steel cutters, will not give the necessary heat for high-speed steel. A gas and air furnace for twist drills and smaller milling cutters is very convenient, and must be accompanied by a suitable set of air-cooling tubes. Twist drills should be both heated and cooled vertically to prevent warping. The writer had to harden some Mushet high-speed milling cutters 14 inches diameter, also a number of cutters 12 inches long by 5 inches diameter, and the problem was to obtain sufficient heat without damaging the teeth. This would not have been possible in a smith's hearth, and none of the gas furnaces available were large enough. The following method was devised: Some lead was melted in a crucible melting-pot, and the cutter, after being well soaked through in a supplementary furnace, was lowered by means of a bar through the hole of the cutter into the molten lead, and left there until the necessary heat was obtained. In the case of the 14-inch diameter cutter a special pot was made and supported on three brick piers. Another hardening problem was solved as follows: A Mushet high-speed twist drill, 4⅞ inches diameter by 24 inches long, had to be hardened. A cyclone gas furnace was used, but after sand-blasting the drill it was found to have two longitudinal cracks up each side. So it was decided to harden the replace drill out of the smith's hearth; it was soaked for twelve hours and finally brought to a full yellow heat, the drill being constantly turned round in the fire. When the desired heat was obtained, it was placed in a specially prepared tube connected with an air-blast.

The testing at Clyde Works of the old Mushet steel was done on a 14-inch lathe, with 4-inch belts driven by a 19 horse-power gas-engine. Mushet high-speed steel soon showed this lathe insufficient in power, so a 16-inch high-speed lathe with five cones, 6 inches wide, was obtained. The line shaft was arranged with two pulleys so that ten speeds are available, and by varying the gas-engine from 160 to 210 revolutions practically all desired speeds can be obtained on the gradually diminishing shafts. The 19 horse-power engine soon had to be replaced with a 36 horse-power engine. All the steel shafts used are of open-hearth steel, made at the writer's works, and cast iron only of the hardest degrees obtainable is used. At first the softest qualities of steel were operated upon, but such quantities were turned away before any conclusions could be drawn that only hard and extremely hard tempers are now used. A specimen test-sheet as used by the writer is reproduced:—

Tool.	Shaft.	Diameter.	Revolutions.	Feet per Minute.	Traverse.	Length.	Cut.	Result.	Remarks.
		Ins.							
Mushet high-speed, 1 in. sq.	Hard steel	13	12	40	$\frac{1}{16}$	22½	1¼	Tool good	30 mins.
					Removing 5·2 lbs. per minute.				
Mushet high-speed, 1½ in. sq.	Hard steel	12½	15	45	⅛	18¾	1¼	Tool good	10 mins.
					Removing 12·15 lbs. per minute.				
Mushet high-speed, 1¼ in. sq.	Oil-hardened axle	8⅞	24	56	⅛	13 ft. 10 in.	⅜	...	Without a grind

In turning up Mushet high-speed steel blanks for twist drills, Mr. Gledhill's statement can be confirmed about the finish obtainable with high-speed steel if a fine feed be used even at the highest cutting speeds. It is the custom at Clyde Works to turn these blanks at from 80 to 160 feet per minute. The finishing cuts are done with feeds of 92 cuts per inch of traverse, and this leaves an extremely smooth surface. For the finish on such articles as piston-rods, where a scraping tool is required, the writer strongly recommends a modification of a high-speed steel, a special one being made at Clyde Works, viz.: Regarding twist drills made of high-speed steel, the absolute necessity of the points being ground on a pointing machine ought to be thoroughly realised. A powerful testing machine has been obtained by the writer's firm, it being specially built by Messrs. Tangyes, Ltd. The drill-head is fixed on a slide supported at each end by powerful uprights. The spindle is 3-inch diameter, and is speeded to run at from 78 to 526 revolutions per minute. The feeds are from 0·79 to 17·02 inches per minute. It has been found possible to drill at the following speeds:—

Class of Steel.	Size of Drill.	Nature of Material.	Revolutions per Minute.	Revolutions per Inch of Feed.	Depth of Hole.	Feed in Inches per Minute.
	Ins.				Inches.	
Mushet high-speed	$1\frac{5}{8}$	Cast iron and very hard steel	181	30·9	3	5·85
Do.	1	Cast iron	269	49·2	3	5·47
Do.	$\frac{13}{16}$	Very hard steel	449	49·2	3	9·13
Do.	$\frac{13}{16}$	Very hard steel	526	49·2	3	10·69
Do.	$\frac{13}{16}$	Cast iron	526	38·6	3	13·62
Do.	$\frac{1}{2}$	Do.	526	30·9	3	17·02*

The practice in making Mushet high-speed steel twist drills s to cut the flutes with the cutters revolving at the rate of 80 feet per minute.

A cordial vote of thanks having been passed to Mr. Gledhill, Mr. Windsor Richards then announced that the papers by Mr. E. Demenge, and by Mr. Andrew McWilliam and Mr. W. H. Hatfield, Sheffield; and the report on carbon and phosphorus would be taken as read, and proposed votes of thanks to the authors, which were carried unanimously.

Votes of Thanks.

Mr. E. Windsor Richards, Past-President, proposed a vote of thanks to the President of the American Reception Committee, Mr. John Fritz; to the Chairman of the Executive Committee, Mr. Charles Kirchhoff, and the Hon. Secretary, Mr. Theodore Dwight; to the Members of the Reception Committee, and also to the Local Committees in New York, Philadelphia, Washington, Pittsburg, Cleveland, Buffalo, St. Louis, and Chicago, for the great cordiality of the welcome extended, and for the arrangements so ably planned and so successfully carried out for the convenience, instruction, and pleasure of the members during the meeting.

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* At the latter feed of 17·02 inches per minute, a large number of holes have been drilled consecutively.

The vote of thanks was seconded by Mr. **Bennett H. Brough**, Secretary, and acknowledged by Mr. **George W. Maynard**, Vice-Chairman of the New York Reception Committee.

Sir **James Kitson**, Bart., M.P., Past-President, proposed that the best thanks of the meeting be given to Mr. Carnegie for his able conduct in the chair. Those who preceded him in the chair were conscious of the fact that it was not the simple duty of conducting the proceedings that laid a burden upon the Chairman. He had a good deal to organise, and he had a good deal to arrange. It was due, in the first place, to Mr. Carnegie's initiative that the Institute had the great honour and the great pleasure of being invited to visit the United States. Reference had been made by Mr. Gayley in his paper to the creation of energy. It was perhaps hardly necessary to attempt the creation of energy in the United States amongst any section of her citizens, least of all amongst that section which controls the magnificent iron trade. It was, however, clear that Mr. Carnegie had succeeded in energising the energetic, and although he claimed that he owed success to the fact that he had found out and used men much cleverer than himself, he had nevertheless been so successful in this organisation, and also in his management of the Institute's affairs here, that members would join in voting that the best thanks be given to him for his conduct on this occasion.

The vote of thanks was seconded by Mr. **E. P. Martin**, Past-President, and carried with acclamation.

The following papers were taken as read:—

THE UTILISATION OF EXHAUST STEAM, FROM ENGINES ACTING INTERMITTENTLY, BY MEANS OF REGENERATIVE STEAM ACCUMULATORS AND OF LOW-PRESSURE TURBINES ON THE RATEAU SYSTEM.

BY EMILE DEMENGE, PARIS.

IF one of the numerous engines acting intermittently, and employed in industrial operations, particularly at steel works or at mines, be carefully watched during working, it is difficult to avoid being struck by the enormous volumes of steam which such engines discharge, with total loss, into the atmosphere.

Certain peculiarities, inherent to the method by which such engines work, render the condensation of this waste steam a matter of difficulty, or minimise the advantages to be derived therefrom, hence in many of them it is allowed to escape freely. On the other hand, it is often impossible, for similar reasons, to adapt to these machines the many improvements which have been applied to other steam engines of the piston type: multiple expansion, the use of superheated steam, &c.

The result is that the steam consumption of such engines is relatively very high. Thus, it is particularly noticeable in steelworks, where, without counting the numerous secondary machines which discharge free steam, the reversing engines in the rolling-mills alone will discharge steam into the atmosphere, absolutely uselessly, to the extent of 35,000 to 45,000 lbs. of steam per hour.

Now, if the difference between the pressure, at the moment of escape, and that of a vacuum in a condenser, corresponding to 26·5 inches of mercury, be taken into consideration, this quantity of steam would be capable of developing, in theory, 1700 to 2200 horse-power. Herein lies, therefore, a highly important source of energy, the recovery of which presents the greatest interest to modern industry, which seeks by every means to develop motive power under conditions of economy, both to reduce the cost of production and to withstand competition.

Mr. Rateau, Professor at the École des Mines, Paris, has specially devoted himself to the interesting problem of the utilisation of exhaust steam, and has obtained highly remarkable results by means of the regenerative steam accumulator which he has devised, in combination with low-pressure turbines, which can be coupled directly to dynamo machines, pumps, or centrifugal fans.

THE NATURE AND FUNCTIONS OF THE REGENERATIVE STEAM ACCUMULATOR.

The "primary machine" * discharges its exhaust steam intermittently; on the other hand, the turbine requires a regular supply of steam to feed it. The regenerative steam accumulator serves to effect this regulation of the steam supply.

The principle upon which the machine is based involves considerations as to the properties possessed by saturated steam and saturated liquids respectively, and of the heat exchanges which take place between the steam and the water, either directly or through the medium of metallic partitions. Under any determined conditions of pressure and temperature these two fluids—saturated steam on the one hand, and steam-saturated water on the other—composed as they are of similar molecules, preserve a reciprocal condition of equilibrium, such that any variation in the total heat of the system, which may result from a disturbance of this equilibrium, determines the transformation of either form of fluid into the other form, with a corresponding absorption of heat in the one case or liberation of heat in the other. Given this property, it follows that if the steam which is escaping intermittently be conducted into a receiver containing cast iron and water, the cast iron will absorb heat and occasion, upon its surface, the condensation of a certain quantity of steam, which remains in the state of saturated water. Owing to this condensation, the steam accumulates whenever an abundant supply arrives in the accumulator, and thus causes a slight elevation both of

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* By "primary machine" is meant the source from which the accumulator derives its power.

temperature and of pressure within the apparatus. When the supply of exhaust steam from the engine falls off or ceases, the steady call for steam for the turbine reduces the pressure, and so determines the condition of dis-equilibrium, the necessity for which has already been explained. The latent heat of the steam, held in reserve by the cast iron and the water, serves to vaporise anew a certain weight of water, and the steam is thus regenerated in the form of a constant supply. These exchanges take place with extreme rapidity, and the variations of temperature and pressure required for the condensation and regeneration of the steam in the interior of the accumulator correspond with these slight fluctuations, which can be perfectly controlled by a careful adjustment of the materials contained in the apparatus and by regulating the escape valves. This is, in principle, the function of the Rateau regenerative accumulator. Its action can best be compared with that of the flywheel of an engine. It plays the same part, as a reserve for heat; it is, in fact, a true flywheel for heat. The solid materials contained in the apparatus only serve, as we have seen, to facilitate the heat exchanges between the water and the steam. If, therefore, it were possible to determine these exchanges without using cast iron, a system at once more economical and of simpler construction would be realised. It will be seen presently that Mr. Rateau has attained this object by means of his water accumulator.

In practice the regenerative steam accumulator consists of a cylindrical vessel of sheet metal enclosing either a series of cast-iron trays or water only.

COMPOUND ACCUMULATOR WITH CAST-IRON TRAYS AND WATER.

This was the first type studied by Mr. Rateau, and the apparatus has already received the sanction of usage, an accumulator of this construction having been in actual operation at the Bruay Collieries, in the Pas-de-Calais, since August 1902.

The compound accumulator consists of one or more cylindrical drums, disposed either horizontally or vertically, and enclosing a succession of cast-iron trays filled with water (Fig. 1). The steam enters at D, and is distributed over the trays by the

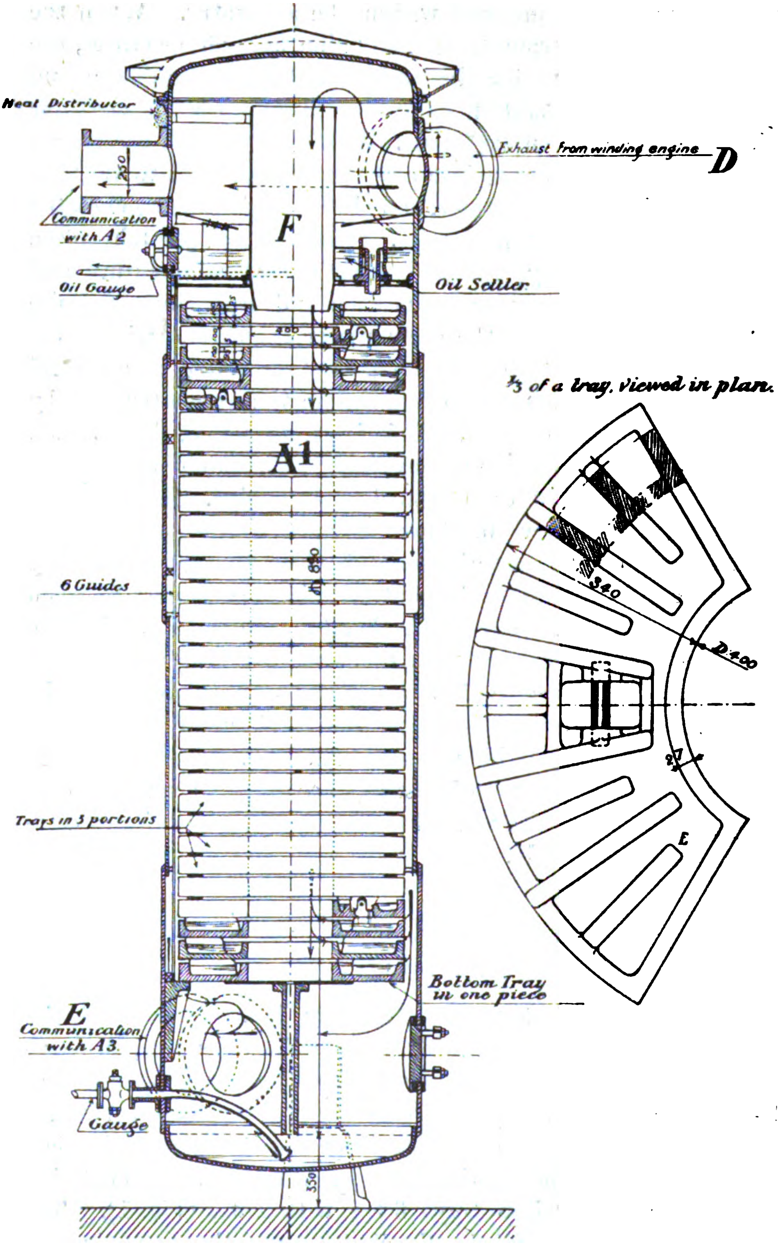

Heat Distributor
250
Communication with A2
Oil Gauge
Exhaust from winding engine
D
F
Oil Settler
400
A1
880
6 Guides
Trays in 3 portions
Bottom Tray in one piece
E
Communication with A3
Gauge
350
⅓ of a tray, viewed in plan.
340
D 400
27
E

FIG. 1.

central passage F; the regularly maintained current of steam passes out at E. The drums are surrounded by a heat dissipator.

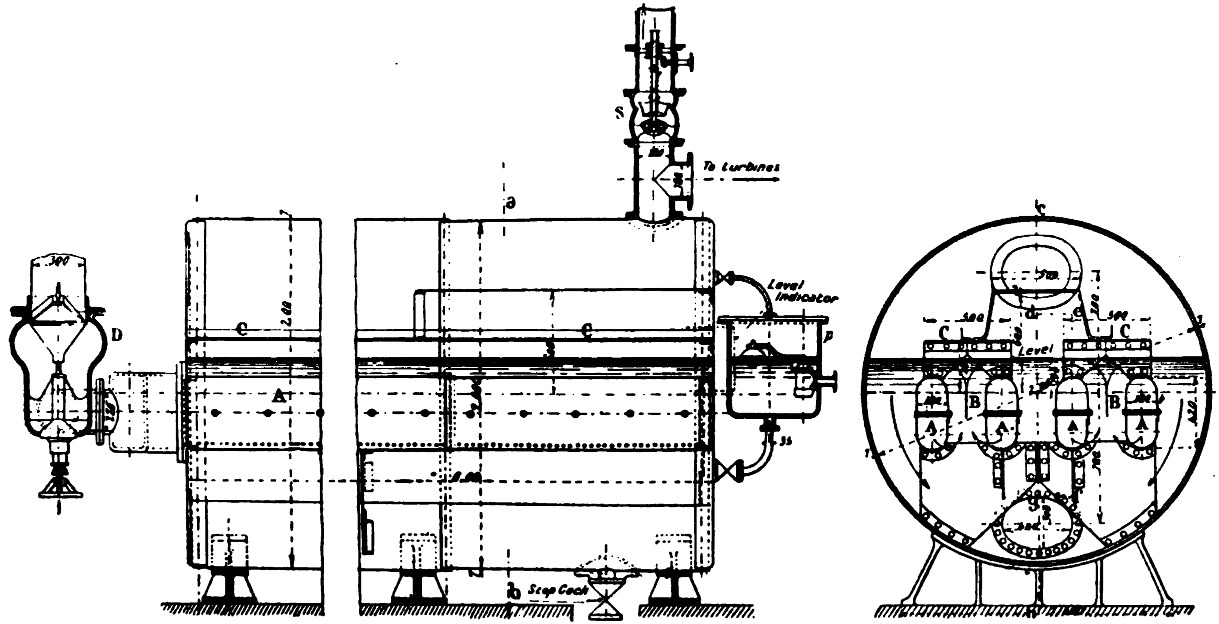
SIMPLE WATER ACCUMULATOR.

In this apparatus the heat fly-wheel consists simply of a mass of water. The economy in the cost of installation is highly important, as water costs nothing. This liquid is, however, a bad conductor; it would appear difficult to impart to it rapidly the large amount of heat corresponding with the latent heat of the steam to be condensed. Mr. Rateau has overcome this difficulty by occasioning, in the very centre of the liquid, energetic circulation, so as to increase the amount of contact taking place between the steam and the molecules of water.

The accumulator (Fig. 2) consists of one or more horizontal cylindrical bodies composed of boiler plating, in the interior of which are arranged a number of tubes, A, of elliptical section, which traverse the cylinder from end to end, leaving between them the intertubular spaces B.

The steam enters the tubes A, and escapes violently into the spaces B, through a number of minute orifices driven in the sides of the tubes. The circulation of the water takes place in the direction of the arrows; the plates C, placed above the intertubular spaces B, interrupt the flow of the water, and prevent it being projected upwards. This flow of steam gives an extreme degree of emulsification to the water, which becomes steam-saturated. When the source of supply is stopped, the water liberates the latent heat it has absorbed, and the steam escapes in a steady stream; at the same time the regular demand of the low-pressure motor, which utilises this steady supply, reduces the pressure within the accumulator, and the steam still retained in the inner tubes continues to escape through the orifices, which confers on the liquid a degree of circulatory motion that facilitates the liberation of the steam. It has been clearly shown by Mr. Rateau's experiments that the whole of the water contained in the accumulator participates in the regenerative action.

Besides these two fundamental types of accumulators, there exists a third, which can be utilised under certain special



Section on *c*, *d*, *e*, *f*, *g*, *h*.

Section on *a*, *b*.

FIG. 2.—Longitudinal and Transverse Sections of the Water Accumulator.

circumstances. It is shown in Fig. 3, which represents the "scrap-iron" accumulator. Any cylindrical vessel, *e.g.* an old boiler shell, can be utilised, and filled with old iron, scrap, old rails, &c. The advantage derived from the heat flywheel action of the water contained in the tubes of the compound accumulator is not obtainable by this apparatus, but if the necessary materials are at hand a cheap accumulator is obtained in this manner.

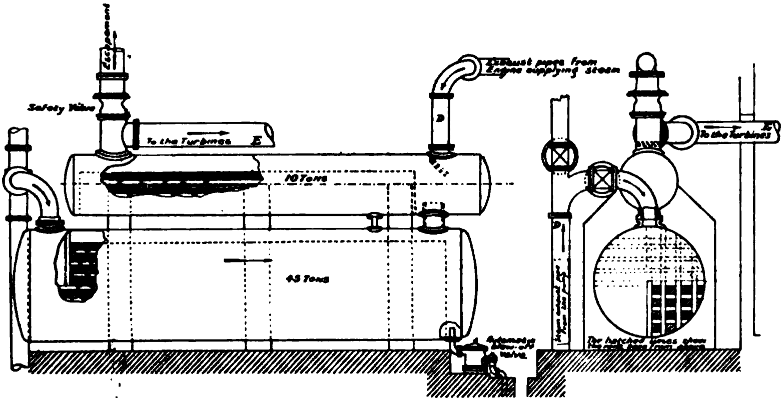


FIG. 3.

The system has already been put into operation at the Réunion Collieries of the Madrid-Saragossa-Alicante Railway Company in Spain.

ACCESSORY APPLIANCES OF THE ACCUMULATOR.

The installation of an accumulator entails the provision of a certain number of accessory appliances, amongst which may be mentioned the open-air escape valve. This valve (Fig. 4) allows of the free discharge, either into the atmosphere or into a condenser, of the exhaust steam from the source of supply, when this is not required by the low-pressure machine, either because the latter is working at slow speed or because it is stopped altogether. For this purpose a double-seated valve is employed, in order to secure a large area of escapement with low leverage. The pressure of the steam is counterbalanced by a spring which acts directly upon the valve, and as this spring can be tightened at will, it is possible to regulate the pressure necessary for the escapement as required. An automatic supply valve is also furnished, so that when the demand for steam exceeds the supply available from the engine, it allows of the direct arrival of steam from the boilers. It may be observed that no inconvenience arises on drawing off steam from the boilers when the engine ceases to furnish exhaust steam; on the contrary, it serves to regulate the working of the boilers. At the same time, this steam is not utilised at its initial pressure, nor does it produce, in the secondary motor,

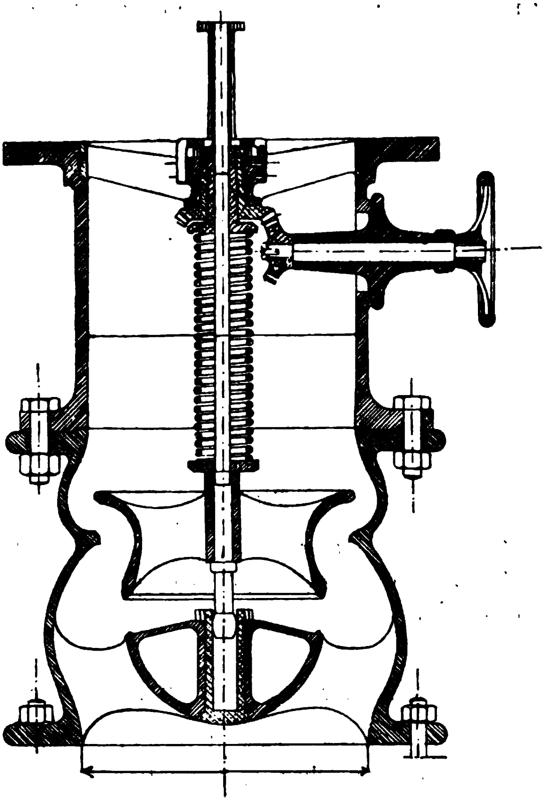


FIG. 4.—Atmospheric Escape Valve of the Steam Accumulator.

the full effect which it is capable of developing. It will be seen later on how this disadvantage has been completely overcome. The accumulators are furnished, in addition to the two accessories, with a steam stop-valve, a water stop-valve, and an automatic blow-off valve.

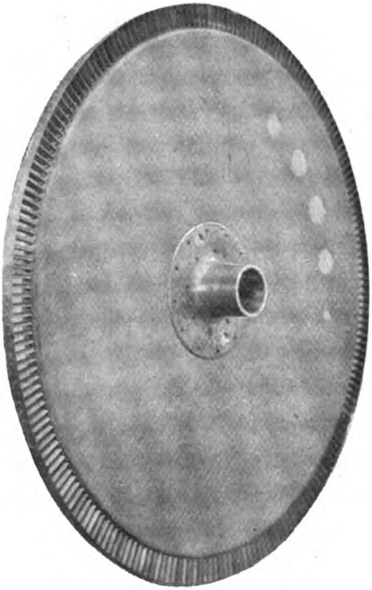


FIG. 5.—Rotating Wheel of a Rateau Turbine.

LOW-PRESSURE SECONDARY MACHINE.

The steady current of steam regulated by the accumulator goes to feed a low-pressure motor. This could, theoretically, be a piston machine, but the steam pressure being, on admission, not far removed from that of the atmosphere, such a machine would require cylinders of large dimensions, in which considerable condensation would take place, and the efficiency of such a motor would be very low. On the other hand, a low-pressure turbine yields its greater efficiency with low-pressure steam. For the utilisation of exhaust steam almost any turbine would

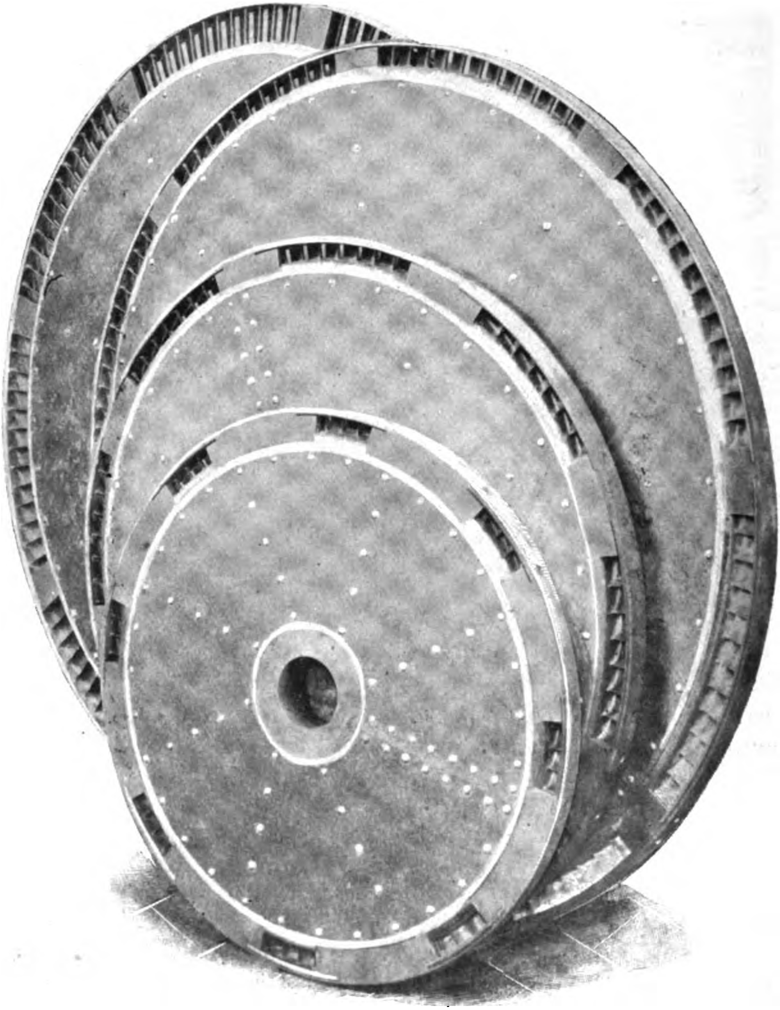


FIG. 6.—A Series of Distributors.

be adaptable, but Mr. Rateau has studied the type more especially adapted to work with a supply of low-pressure steam.

The Rateau turbine is now universally known, and it would be useless to repeat the description of it, particularly as the author himself has so lucidly set out the principal advantages of his remarkable system in the communication made before the meeting of the American Society of Mechanical Engineers, this year. Mr. Rateau also referred to the mixed turbine. These turbines having an important bearing on our subject, it would be well to recall, briefly, the special advantages they present for the rational regeneration of waste steam.

COMPOUND TURBINE SYSTEMS.

During those periods when the low-pressure turbine is fed with live steam coming directly from the boiler, and previously expanded, its consumption per horse-power hour will evidently be higher than it would be under similar conditions in an engine working in the ordinary way, with the full pressure of the boilers, 33 lbs. per horse-power hour, for example, instead of 22 to 26·5 lbs.

If the engine which supplies the exhaust steam is working fairly regularly, the demand for live steam will only arise for a small proportion of the total time, so that the somewhat increased consumption during this period will have but little influence on the gross cost. This will not, however, always be the case, as, for example, when the secondary plant is required to work regularly throughout the night as well as during the day.

It is possible, therefore, to so arrange conditions that the turbine may at all times work as economically as possible, by supplementing it with a high-pressure turbine, intended to take the steam direct from the boilers during stoppages of the engine furnishing exhaust to the low-pressure plant. The exhaust from the high-pressure turbine can be utilised by the low-pressure turbine, which can thus derive its supply either from this source or from the accumulator. This group of a pair of turbines must be regarded as a high-pressure system, capable of at all times receiving and utilising to the best advantage steam derived from

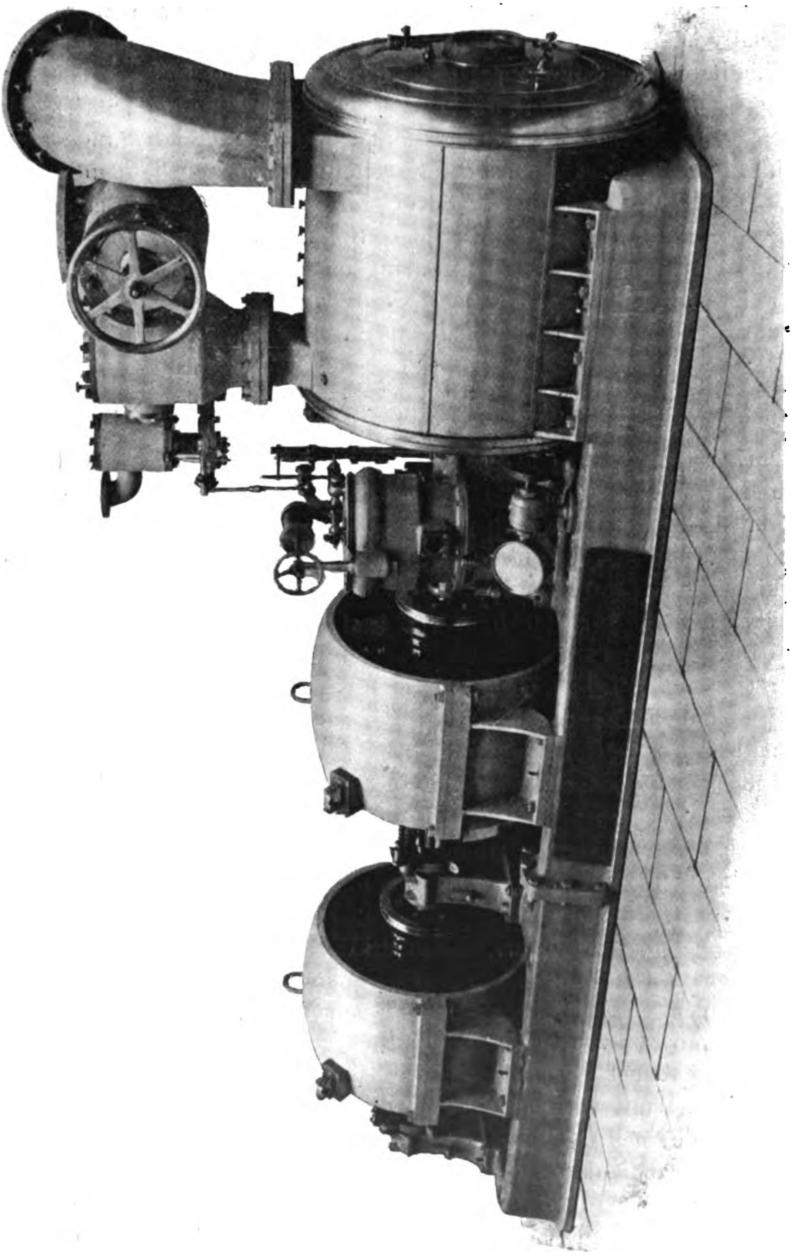


FIG. 7.—View of the Exterior of the Turbine at Bruay.

primary sources. It is to be understood that the admission of live steam at high pressure, as well as of that at low pressure, is automatically controlled, according to requirements, by an appropriate regulator.

With an ordinary vacuum this group will only consume 17·6 lbs. of steam per electric horse-power when working at full speed, with, for example, a feed at 114 lbs. per sq. in., and, as has already been shown above, 26·5 lbs. to 36·5 lbs., according to conditions, if it requires only exhaust steam at atmospheric pressure.

By the simple arrangements just outlined, the engine is enabled to work continuously under the most advantageous conditions. During the time that there is no exhaust steam available, it is simply a high-pressure plant using in the most advantageous way live steam; when low-pressure steam becomes available, the plant profits by it by effecting a proportional reduction in the consumption of high-pressure steam. Indeed, the compound high- and low-pressure turbine can be fed, not only by two supplies of steam at different pressures, but by three or four supplies, which cannot be done with the same facility by piston engines. Thus, at the Mines de la Réunion in Spain, the regenerative steam installation comprises two groups of 300 horse-power turbines, which can be supplied either simultaneously or separately with low-pressure exhaust steam or by steam coming from one group of generators at 71 lbs. per sq. in. or from another group at 170 lbs. per sq. in. Fig. 8 represents one of these mixed or compound turbines. In small plants the two engines are usually combined in one shell.

ADVANTAGES OF THE RATEAU SYSTEM EMPLOYED WITH CENTRAL CONDENSERS.

If a central condensing plant is already installed, the accumulator and turbine can be interposed between the condenser and the sources of supply. Besides the much more economical utilisation of the power thus obtained, this arrangement possesses the advantage, in cases where the pressure of the steam furnished to the turbines is above that of the atmosphere, of preventing the entry of air into the connections through which the steam passes.

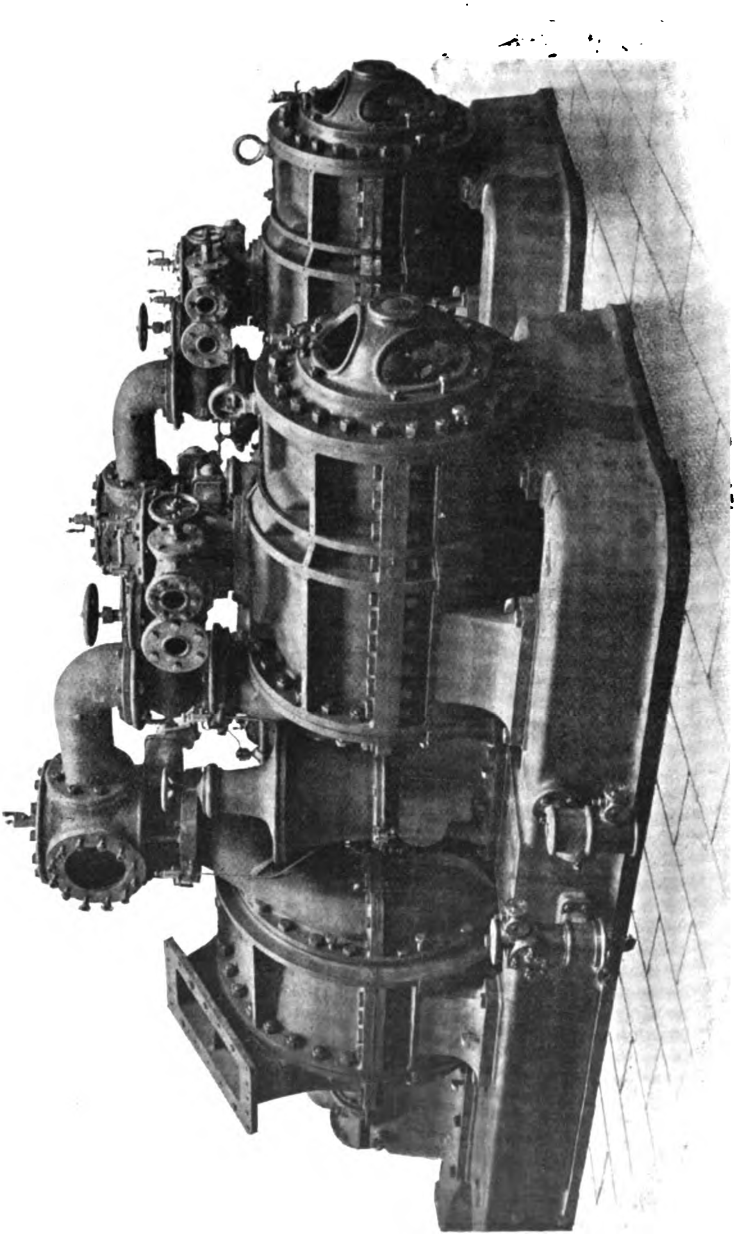


FIG. 8.

It must be noted, however, that the turbines can be supplied with steam at a pressure lower than that of the atmosphere, if it is undesirable to sensibly reduce the counter-pressure of the main engine and so impede its working. Even with pressure only one-half that of the atmosphere, it is still possible to obtain, as will be seen from Table I., an electric horse-power of 36·4 lbs. of steam per hour.

It may appear, *a priori*, strange that in these various instances the interposition of an accumulator-turbine group should be more efficient than simply allowing the condenser steam to feed the engines in the ordinary way. The benefit accrues from the fact that the turbines allow of the expansion of the steam being carried to its extreme limit, and that they still yield an excellent result with low pressures, whereas the reverse is the case with piston engines. With turbines it will be found that 65 to 70 per cent. of the power theoretically available, through expansion from atmospheric pressure to that of the condenser, is obtainable, while piston engines only yield under these circumstances 35 to 40 per cent. of the same power. In other words, a far better result is obtained from the calorific energy available in the steam from the boilers when, for high pressures, piston engines are employed, and, for low pressures, turbines. Calculations show still more clearly the justification of the foregoing claim. Suppose, for example, that the average consumption of the engines, freely discharging exhaust steam into the air, be n lbs. per useful horse-power per hour, we can determine the benefits arising—

(1) From the application of condensation in the ordinary way.

(2) From the addition to the installation of an accumulator-turbine system.

I. Condensing corresponds to a saving in consumption of 15 to 20 per cent., so that under these conditions each useful horse-power developed by the engines supplying exhaust corresponds to the supply of steam equalling $0{\cdot}2n$. If this available steam be employed in a high-class motor of the piston type, actuating a dynamo, and consuming, say, 16·5 lbs. per electric horse-power hour, the increased power obtained will be

$$\frac{0{\cdot}2n}{16{\cdot}5} = \frac{n}{82{\cdot}5} \text{ electric horse-power.}$$

II. By employing a turbine the exhaust steam at atmospheric pressure will develop one electric horse-power per 31 lbs. of dry steam expended. The weight n escaping from the boilers will yield about $0{\cdot}8n$ of dry steam, allowing for 20 per cent. of condensation in the primary engine and the connections. This weight ($0{\cdot}8n$) of steam would be capable of developing in useful work

$$\frac{0{\cdot}8n}{31} = \frac{n}{38{\cdot}7} \text{ electric horse-power.}$$

Thus, in the second case an efficiency more than double that of the first is obtained.

The relation between these two figures is, by the way, quite independent of the degree of perfection to which the primary machine might be brought.

TABLE I.

		Pressure of Supply in lbs. per sq. in.		
		28·4	14·2	7·1
Pressure of exhaust in lbs. per sq. in.	1·13	20·5	26·5	36·4
	1·85	23·6	31·8	47·5
	2·56	26·5	36·4	61·8

If it is desired to benefit the primary machines by a certain degree of condensation, there is nothing to prevent the feeding of the turbines with steam at a pressure below 14 lbs. per square inch. Table I. shows the actual consumption of steam which can be obtained under the various conditions realised in practice. The first horizontal column corresponds to the employment of a surface condenser with a vacuum of 27·5 inches of mercury; the second, to a mixed condenser with a vacuum of 26 inches of mercury; and the third, to an ejector condenser giving a vacuum of 24·6 inches of mercury.

The central vertical column relates to the normal case in which the turbine employs steam at atmospheric pressure; the first, to the case in which, with the object of developing the full advantage available from the turbine, the pressure of the exhaust steam has been raised to 42·6 lbs. absolute pressure per square inch; and the third corresponds to the employment by the turbine of an exhaust at only one-half the atmospheric pressure, when it is undesirable to hamper the working of the primary engine.

It may happen, in a plant consisting of primary engines, an accumulator-turbine system, and a central condenser, that the turbine will work during a portion of the day at slower speed. It is only necessary in this case—the free exhaust valve being adjustable—to reduce the resistance of the spring controlling the latter to establish a low pressure of, say, 7·1 lbs. per square inch throughout the whole system. The engines will thus derive a large proportion of the benefits arising from condensation, and the running of the turbine will be still more economical, for, as has been already indicated, it is possible under these circumstances to obtain an electric horse-power with a consumption of only 46·5 lbs. of steam per hour.

If there is nothing to prevent the reduction of the pressure of the exhaust from the primary engine, even greater advantages accrue. Take, for example, an engine consuming, with free exhaust, 13,200 lbs. of steam per hour, with an average of 100 lbs. per useful horse-power. Let us also assume the absolute steam pressure to be 71 lbs. per square inch on admission to the power cylinders. If exhaust takes place at atmospheric pressure, the consumption of the turbine per electric horse-power hour will be about 31 lbs. The 13,200 lbs. of steam expended by the primary engine, reduced by condensation to 10,600 lbs., will therefore furnish the turbine with a supplementary supply of power of

$$\frac{10{,}600}{31} = 341 \text{ electric horse-power,}$$

or a total of 471 useful horse-power, which makes the consumption, per useful horse-power, per hour, about 28 lbs.

If the pressure of the initial exhaust be now raised, say, to 42 lbs. per square inch, the steam will have to be introduced at a pressure of 100 lbs. per square inch, at least, instead of 71, and the area of inlet increased by about 25 per cent. in order to furnish a similar system with the same amount of power. The consumption per hour will then become, approximately,

$$13{,}200 \times \frac{100}{71} \times 1{\cdot}25 = 23{,}100.$$

The turbine will therefore benefit to the extent of 0·8 × 23,100 = 18,600 lbs. of dry steam per hour, at a pressure of 42 lbs. per square inch. With this supply the consumption of the turbine per electric horse-power and per hour will fall to about 22 lbs. The power rendered available by this means becomes

$$\frac{18{,}600}{22} = 850 \text{ electric horse-power,}$$

that is to say, it rises to nearly treble the amount developed in the former instance.

23,100 lbs. of steam would yield a total of 980 horse-power, which reduces the consumption of the system per useful horse-power per hour to about 23·5 lbs. instead of 28, which was the case with steam escaping at 14 lbs. per square inch.

These figures are much in advance of those usually obtained, even in the most highly perfect engines.

SAVING EFFECTED.

The economy resulting from the application of the Rateau system can be ranged under two heads.

1. *Saving in the Cost of Installation.*—If the first cost of a turbo-electric plant with accumulator be compared with that of an electric plant with a piston engine and boilers, there is a marked saving in favour of the former. The difference arises from the substitution of a regenerative accumulator for the other sources of steam supply, which are much more costly, and also from the much lower first cost, and cost of laying down of the electro-turbine as compared with the cost of dynamos and piston engines capable of developing the same power. It is natural that the relative importance of these various elements should vary according to the additional power required, the weight of the accumulator, or the conditions under which the prime motor works, and of the general method of exploitation. The great variations in the cost of engines are also an important obstacle in the way of

giving exact figures. It follows, however, from the comparative estimates made between the different combinations intended to produce a certain power by the method of the accumulator and turbine, and again by piston motors with the ordinary generator, that the economy of setting up the plant by the Rateau system is always clearly marked, and may, in the case of attaining 500 horse-power, for example, reach £1600 to £2000. Furthermore it is well to note, that when a central condenser exists, it can be utilised for the low-pressure turbine, while an electric unit driven by live steam needs, as a rule, a special condenser.

2. *Saving in Cost of Working.*—This item is obtained by the reduction of the number of men employed at boilers; by the lowering of the amounts to be set aside for redemption; cost of installation and interest on capital; and, in particular, by the diminished consumption of fuel.

If the preceding example of a 500 horse-power electric installation be again taken, and a daily shift of twenty hours be assumed, the annual saving will work out as follows:—

Saving in coal over 300 days at 1·2 kilogrammes per horse-power (coal at 10s. per ton)	£1728
Saving in reduction on capital charges and on interest on capital, say, at 15 per cent. on £1600, for example	240
Wages for two stokers, say	148
Saving in lubricating oil, about	200
	£2316

The estimate for the cost of fuel is, of course, arbitrary. The saving realised at some collieries where the selling price of coal is but 7s. 6d., 5s., or even 4s. per ton, will be somewhat lower. On the other hand, at some steelworks where the usual price of coal ranges from 12s. to 16s. per ton, and where the engines run, as a rule, day and night, the annual saving in such cases as those under consideration would amount to nearly £4000 for a daily average of twenty-four hours. In such cases the cost of installation would be recovered within eighteen months by the saving in coal alone.

Applications of the Rateau Process already in Operation.

The process was applied for the first time at Bruay, where, since August 1902, when it was installed, it has given very satisfactory results. Mr. Rateau has, in his recent communication to the American Society of Mechanical Engineers, given a complete description of this installation, and has shown, amongst other points which it is well to remember, that, from experiments which have been made at various periods since its erection, the working of the accumulator has throughout been most regular, and the efficiency of the turbine has been maintained under capital conditions. It must be remembered that, at Bruay, the exhaust steam from a winding engine, regulated, by preference, by means of a mixed accumulator with iron trays, feeds a low-pressure turbine of 300 horse-power, which in turn operates two dynamos coupled up from the same shaft. It is worth noting that since the beginning of May last the turbine has been working steadily, day and night, as would be the case with such installations of low-pressure turbines as would be adopted in steelworks. The complete plan of the installation is shown in Fig. 9.

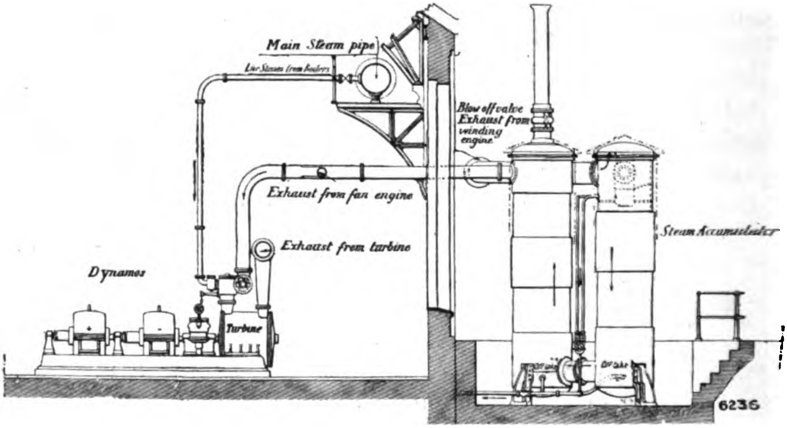


Fig. 9.

Numerous installations of the Rateau system are under observation, or in course of erection, both in France and abroad, at steelworks and at collieries. As particular instances, the plant at the Donetz Steelworks in Russia, and the Poensgen Steelworks at Düsseldorf, the installation of which is on the point of completion, and which presents features of special interest as regards steelworks, may be cited.

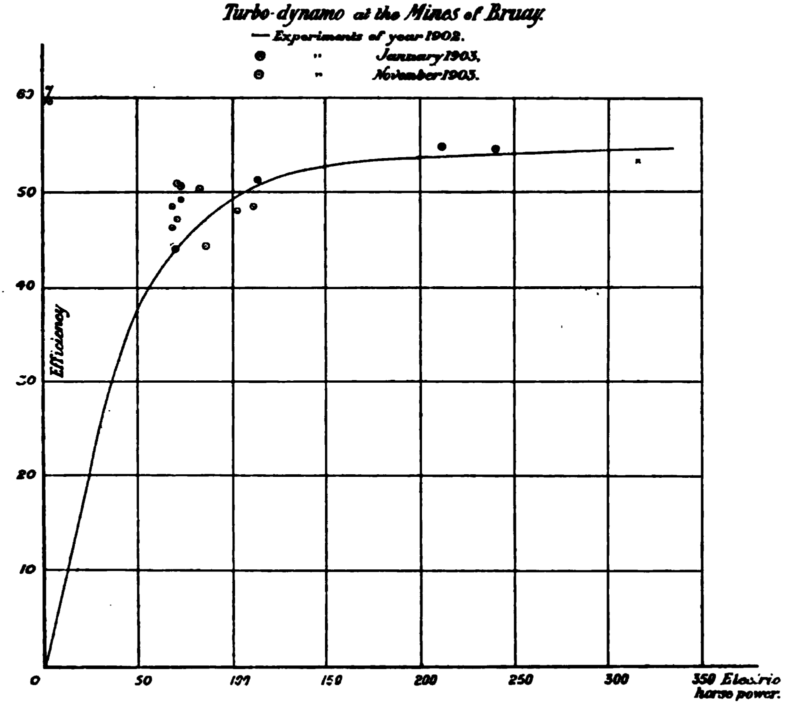


FIG. 10.—Comparative Efficiency of the Turbine at Bruay, at Varying Periods.

Donetz Steelworks.—The plant consists of a double-bodied, horizontal, mixed accumulator, with cast-iron trays and water, capable of controlling 55,000 lbs. of steam per hour, and intended to feed four groups of electric generators of 350 horse-power each. The turbines utilise the exhaust from a three-cylinder, reversible engine driving a rail mill. It is proposed to further utilise the exhaust of a second reversible engine, which will make the total regenerated power equal to 2000 electric horse-power. The energy developed by this powerful central station is intended to light the works, to convey power, to actuate various machines, and for electric furnaces and electric welding purposes.

The Poensgen Steelworks, Düsseldorf.—The management are erecting a mixed accumulator consisting of a single vertical body containing cast-iron trays and water. The plant will serve to regulate a supply of 26,000 lbs. of steam per hour, in spite of the fluctuation of the general supply, which may vary by 810 lbs. The exhaust to be utilised is derived mainly from the rolling-mill engines and the steam-hammers. The regulated current of steam from the accumulator will feed an electromotive group formed by a low-pressure 650 horse-power turbine, and a continuous-current dynamo. It is of interest to note that this plant, which is in course of construction, is to work in connection with a central condenser already in existence. The accumulator will allow of the exhaust from the hammers being taken to the condenser, which has hitherto been regarded as impossible owing to the irregularity and violence of the steam discharge from these machines, which completely destroy the constancy of the condenser vacuum.

Of installations which will very shortly be put into operation, it will suffice to mention the Firminy Collieries in the Loire, the Mines de la Réunion in Spain, and the Mines de Béthune (Pas-de-Calais). The latter should be more especially noted, inasmuch as the low-pressure turbine will be used for the direct driving of a Rateau centrifugal compressor of 350 horse-power, capable of producing 2100 cubic feet of air per minute (measured at atmospheric pressure) under a pressure of 85·3 lbs. per square inch. This is a feature of great interest to steelworks, inasmuch as compressed air, produced, by means of these turbines, at a small cost, could be utilised for blast-furnace purposes, for cupolas, and for Bessemer converters.

These different applications, added to the numerous trials which are actually being carried out on the whole of the plants which have been described, show clearly the interest they present, both from a common-sense point of view and from a practical standpoint. At the present day, when the maximum output with the minimum cost is so sought after, there will certainly be found herein a powerful means for the general improvement of various industries. It is particularly in steel-works and in collieries, where the installation of great central electric plants is the order of the day, that the accumulator provides, through the intervention of low-pressure turbines, a potent supply of electrical power, which can be distributed through the whole works, and even beyond them. The Rateau system thus renders available, at small cost, all the advantages attaching to a large central station, while at the same time avoiding the highly expensive and ticklish installation of rolling machines and winding machines driven electrically. It is this feature which is one of the most considerable of the advantages of the system which, as has already been seen, permits of the reduction of the amount of power consumed by winding engines, or by rolling-mills, to a minimum hardly to be attained by the most highly perfected electrical installations, while at the same time preserving the principal features of such machines, viz., steadiness in working and easy control.

ACID OPEN-HEARTH MANIPULATION.

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and
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At the 1902 May meeting of the Iron and Steel Institute the authors presented a paper on "The Elimination of Silicon in the Acid Open-Hearth," wherein they recorded a few typical examples of certain Siemens charges out of a very large number specially watched for the purposes of that research. The main deductions drawn from those experiments have been accepted in all the intelligent criticism during or after the discussion on the paper. One opinion, however, was rigidly held by all who mentioned the matter, with the single exception, perhaps, of Mr. Lange, and that was the necessity for the attainment and the maintenance of an abnormally high temperature in order that the percentage of silicon in the metallic bath might increase, or that an unusually large proportion of silicon might be retained in the metal. The original decision was arrived at on the results of scores of trials, and has since been the subject of frequent experiment. The authors still retain their opinion that although, naturally, a higher temperature will accelerate the (probable) action between the carbon of the steel and the excess silica of the slag, they then fairly proved, and have now abundantly confirmed the fact, that around the temperatures occurring in Siemens steel-making practice the chemical composition of the slag, particularly with regard to its acidity, is the factor which determines whether the percentage of silicon in the molten steel shall increase or decrease.

In the discussion in 1902 Mr. Saniter called attention to Mr. H. H. Campbell's work, and in the reply the authors also mentioned that of Messrs. Winder and Brunton of 1892, the two latter recording the fact of a rise in silicon, and p. 277, sec. x., *g.*, in the former's excellent work on steel making, reads: "*Conditions Modifying the Character of the Product.*—If the temperature of the metal is very high, the last traces of silicon will not be oxidised, for the affinity of silicon for oxygen is a function of the temperature. . . . Thus the open-hearth cannot rival the converter in producing high silicon metal by non-combustion, but under suitable conditions the amount carried along in the metal may be quite appreciable, and by holding the bath at a very high temperature with a siliceous slag, there will even be a reduction of the silica of the hearth according to the equation $SiO_2 + 2C = Si + 2CO$."

Several heats bearing on this point have been observed, as, for example, one the details of which have been sent recently to the authors, where the carbon of the bath was 2 per cent. at the start, and by adjustment of the slag the silicon was still at 0·4 per cent. when the carbon had fallen to 1·4 per cent.

Despite Mr. Saniter's dictum in the 1902 discussion, although large additions to the bath undoubtedly reduce its temperature, it is not necessarily overheated because no additions are being made to the slag. Consider for a moment the case of turning off the gas and air. By these means it is quite easy to keep the temperature normal without the charging of cold material into the furnace.

The authors then tried the experiment of allowing the metal and slag to interact with only small additions of ore, the temperature ranging from normal to slightly hot, and samples ran as follows: 9 A.M., carbon, 1·55 per cent.; 9·25 A.M., carbon, 1·35; 9·50 A.M., carbon, 1·20, with manganese 0·09 per cent., and silicon 0·60 per cent.

Still further to test the point in as Faraday-like a manner as possible, it was decided to look around for the most siliceous material lying about, that might reasonably be expected easily to enter the slag, and the choice fell on a heap of old red bricks of the following average chemical composition:—

	Per Cent.		Per Cent.		Per Cent.
Silica	78·9	Ferric oxide	4·7	Alumina	13·3
Lime	0·4	Magnesia	1·1		

Eight cwts. of these were thrown into the furnace in three minutes, and after this (to a Siemens charge) "iced drink" the silicon steadily though slowly rose in accordance with the subsequently ascertained composition of the slag.

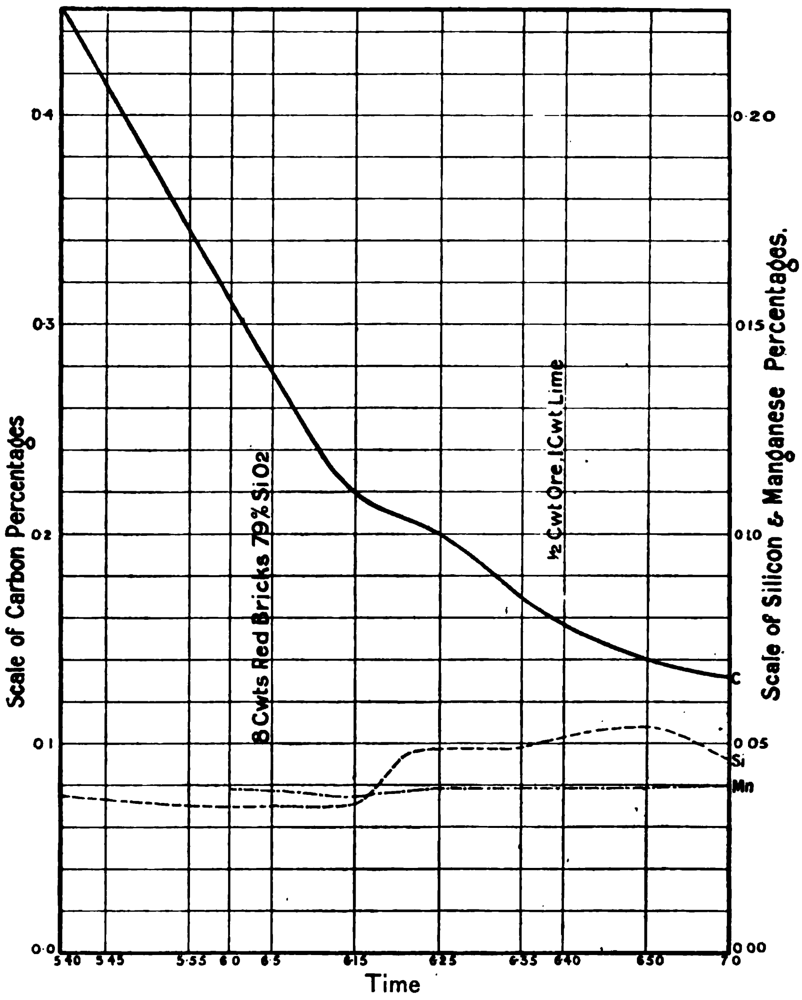

FIG. 1.—Red Brick Charge.

TABLE I.—*Red Brick Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.						
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2.	FeO.	Fe_2O_3.	Al_2O_3.	MnO.	CaO.	MgO.
5	10	...	...	...	Ore	¾	...	...	...	...	...	...	...	...
5	20	...	...	...	,,	1	...	...	...	...	...	...	...	...
5	35	...	...	...	,,	1	...	...	...	...	...	...	...	...
5	40	0·45	0·037	...	...		fairly thin	51·49	24·90	1·74	2·08	17·57	1·10	0·78
5	45	...	...	...	Ore	1	...	...	...	...	...	...	...	...
5	55	...	...	...	,,	1	...	...	...	...	...	...	...	...
6	0	0·31	0·034	0·039	...		moderately thin	...	...	...	...	...	...	...
6	2–5	...	...	...	Red Brick	8	...	...	...	...	...	...	...	...
6	15	0·22	0·034	0·037	...	...	thickening	...	...	...	...	...	...	...
6	25	0·20	0·049	0·039	...	...	thickening	...	...	...	...	...	...	...
6	35	0·17	0·049	0·039	...	...	thick	55·64	21·38	1·27	4·10	15·19	1·38	0·60
6	40	...	...	...	Ore Lime	½ 1	...	...	...	...	...	...	...	...
6	50	0·14	0·053	0·039	...	...	thinning	...	...	...	...	...	...	...
7	0	0·13	0·046	0·04	...	...	thinner	53·98	21·74	0·86	4·43	14 92	2·10	2·08

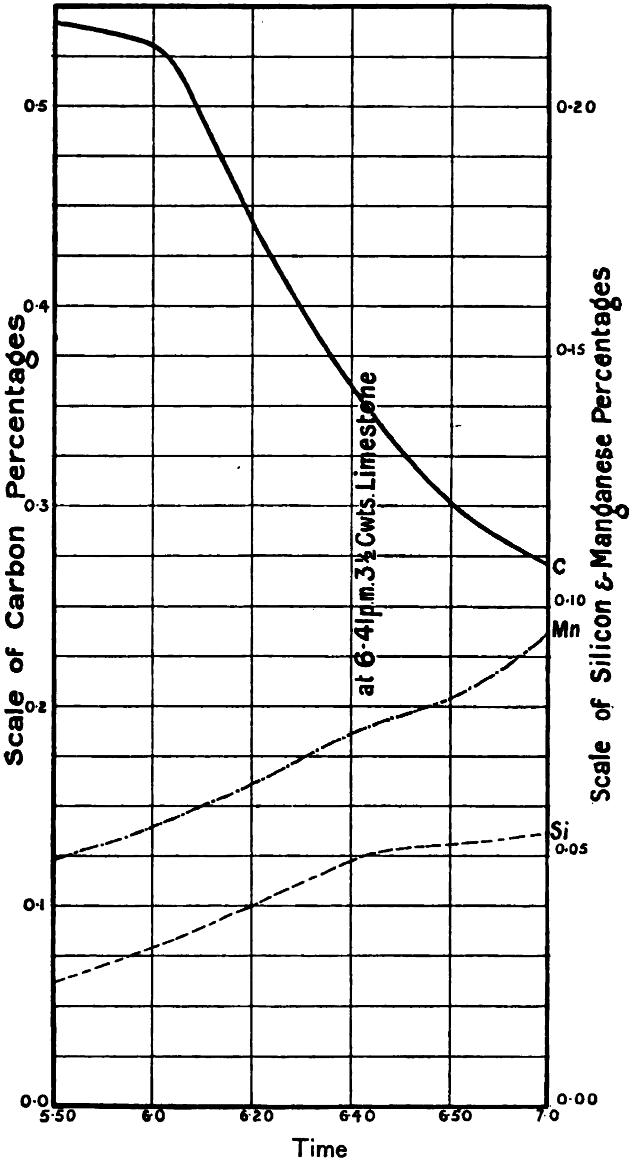

FIG. 2.—Lime Charge.

TABLE II.—*Lime Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.						
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2.	FeO.	Fe_2O_3.	Al_2O_3.	MnO.	CaO.	MgO.
5	50	0·54	0·025	0·049	...	...	fairly thin	...	...	...	...	...	...	...
6	0	0·53	0·031	0·055	...	...	thickening	...	...	...	...	...	...	...
6	20	0·44	0·040	0·064	...	...	thickish	...	...	...	...	...	...	...
6	40	0·36	0·049	0·074	...	...	thick	55·45	18·49	1·61	2·02	20·77	2·09	0·89
6	41	...	...	...	lime	3½	...	...	...	...	...	...	...	...
6	50	0·30	0·051	0·081	...	...	thinning	...	...	...	...	...	...	...
7	0	0·27	0·052	0·096	...	...	thin	53·54	16·59	1·36	1·61	19·77	5·96	1·05

TABLE III.—*Magnesia Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.	
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2	MgO.
3	15	0·44	0·026	0·045	...	...	thinnish	...	...
3	30	0·40	0·029	0·057	...	...	thickening	...	...
3	45	0·29	0·034	0·063	...	...	fairly thick	55·72	3·0
3	50	...	...	...	magnesia	3	...	...	...
4	10	0·19	0·035	0·067	...	...	thinning	...	...
4	28	0·17	0·037	0·074	...	...	thin	54·03	4·0

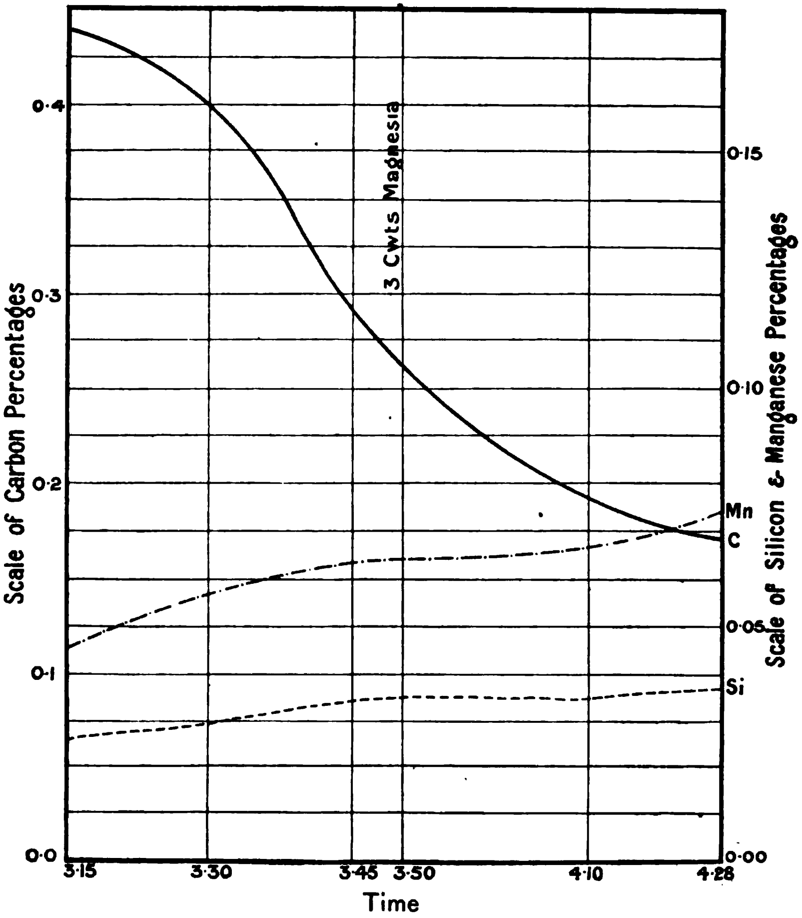

FIG. 3.—Magnesia Charge.

Every one must admit that this addition would cool the bath, and as a matter of fact it became comparatively cold. The details of the experiment are given in Table I., and it will be noticed that before the special addition the silicon was fairly low and slowly falling, while after this addition, which raised the percentage of silica in the slag and cooled the bath, the silicon per cent. gradually increased.

Owing to an apparently abnormal behaviour of the slag in certain trials where a considerable quantity of lime had been added, a special charge was run with the object of watching more closely the effect of lime in the slag on the silicon content of the bath. The slag in one heat was allowed to thicken from 5·50 P.M. to 6·40 P.M., when at 6·41 P.M. 3½ cwts. of limestone were added. This addition had the effect of thinning (increasing the fluidity of) the slag and making it appear more basic than it really was, comparing its fluidity with that of similar slags without lime. Also, with lime present, the balance-point seems to be slightly altered, perhaps owing to the lime not being an oxidising base, and with 53·5 per cent. silica in the slag, the silicon is not lowered but is slowly increasing. This with other results from the experiment, bearing out the general trend of trials made with other ends in view, and hence not followed out in detail at the time, was useful in the making of certain special steels for commercial purposes, but should also be of general interest as an aid to the study of the reactions between metal and slag. The necessary details are given in Table II.

At this stage it seemed "as if increase of appetite had grown with what it fed on," for these results created the desire to know a little of the effect of other and more unusual bases on the slag and steel, so another special heat was run, using magnesia instead of lime.

It will be seen that the magnesia acts after the same fashion as the lime, with the special characteristics perhaps not quite so well defined.

To throw some light on the rather different effect produced by these basic oxides which do not so readily give up their oxygen compared with the oxides of iron, a charge in which the slag should be allowed to thicken as before and then be thinned with the very oxidising manganese dioxide was determined on.

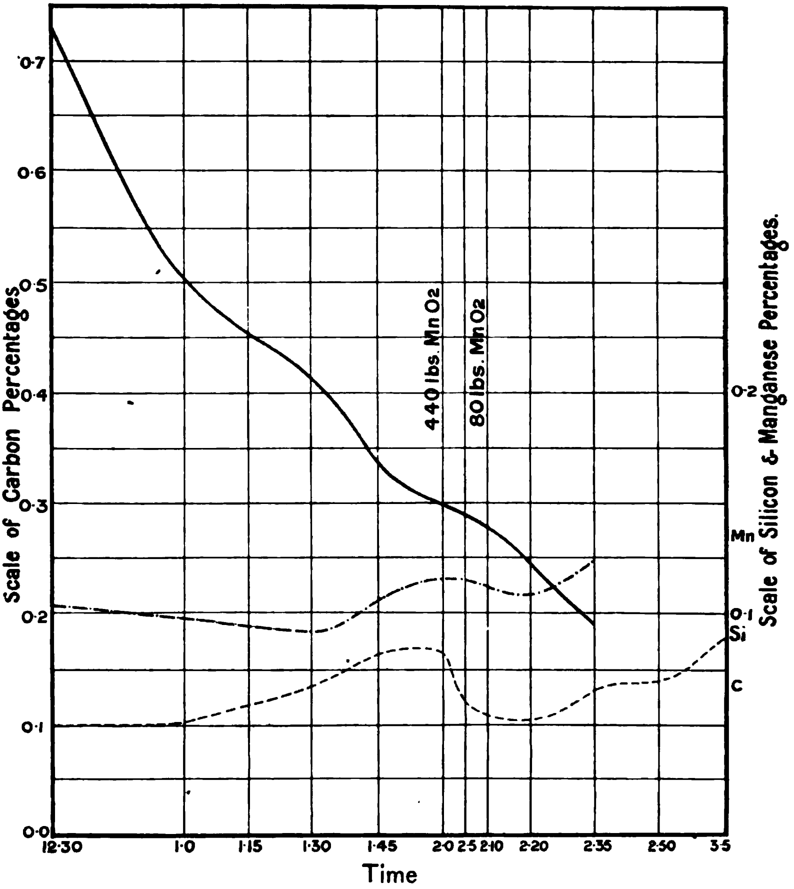

FIG. 4.—Pyrolusite Charge.

TABLE IV.—*Pyrolusite, 22-ton Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.			
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Lbs.		SiO_2	MnO.	CaO.	MgO.
11	45	...	0·20	...	...	...	thin	...	...	...	...
12	30	0·74	0·05	0·104	...	...	thickening	...	...	...	...
1	0	0·51	0·051	0·097	...	...	,,	56·74	16·45	2·96	trace
1	15	...	0·063	...	...	...	,,	...	...	...	...
1	30	0·42	0·069	0·09	...	...	thicker	...	...	...	...
1	45	0·34	0·079	0·111	...	...	very thick	57·62	17·48	...	...
1 to 2	48 0	...	...	...	MnO_2	440	...	...	...	...	...
2	5	0·29	0·061	0·115	...	...	thinning	56·7	18·14	...	...
2	10	...	...	...	MnO_2	80	...	...	...	...	...
2	20	0·25	0·052	0·109	...	...	thinning	55·8	17·4	...	...
2	35	0·19	0.066	0·124	...	...	thin	57·2	18·4	...	...
2	50	...	0·071	...	...	...	thickening	...	...	...	...
3	5	...	(0·09)	...	...	...	,,	64·06	17·97	...	...

In Table IV. are given those details of this charge which are of interest in connection with the experiment. No iron ore was added within the limit of the table, the charge was tapped at 3·10 and behaved normally. It will be seen from the analyses that the carbon continued to fall satisfactorily the whole time, that the 520 lbs. of the black oxide of manganese thinned the slag and made it less siliceous for a short time, but that the new slag quickly helped itself to silica and became viscous and highly siliceous. The source of that silica was evident after tapping, for the appearance of the bottom suggested that as a process for the production of small scale models of the Grand Cañon of Colorado, inaccurate in detail, but faithful to the spirit, it might be recommended, but as a means of making even special steels it would be a little too exciting. From this it will readily be understood why the effect of the more basic slags of the last two series have not been tried and are not likely to be, at least by the present experimenters.

An interesting discovery which is at present engaging the attention of the authors was made during a study of the general notes made of any probable points of interest belonging to the special heats, although these points might not seem to have reference to the more immediate question under observation. It will be remembered that at the May meeting of this Institute Mr. Wahlberg read a paper on some of Mr. Brinell's work on "The Influence of Chemical Composition on Soundness of Steel Ingots," in which Brinell showed that in his practice giving certain relative values for silicon and aluminium in terms of manganese, calculating all out to manganese and taking the total, he obtained a number which he named the density quotient, of such a nature that for the same density quotient he obtained the same type of ingot; for a lower quotient one with more blow-holes, and for a higher quotient, fewer. Now the general experience of the authors has corroborated that of Brinell, but during the progress of this research they made the interesting discovery that those charges treated to one hour's thickening of the slag required a lower density quotient than that for normal heats, to give a certain type of ingot; charges treated to two hours' thickening required a lower number still, while in a heat run specially fast and finished with a much higher density quotient the ingots corresponded to a lower number.

The following figures, and indeed the whole point raised, are given tentatively as a matter of interest, for it appeals to the writers as being of considerable importance, and they are engaged in following the matter up through this and other channels.

Treatment of Charge.	Density Quotient.	Type of Ingots.
Thickening, 2½ hours . . .	0·814	good
,, 1½ hour . . .	1·000	good
Ordinary . . .	1·350	good

The authors have a theory as to the cause of these differences, but prefer to seek further experimental support before making it public.

Again the authors tender their best thanks to willing helpers; to Messrs. J. H. G. Monypenny, H. H. Slater, M. H. Graham, and J. Kilby, for their very careful analytical work, and to Messrs. John Crowley & Co., Ltd., Meadow Hall Iron and Steel Works, Sheffield, England, for the use of a 25-ton furnace, for the purposes of this research.

CORRESPONDENCE.

Mr. J. J. **Morgan** (Workington) hardly thought that the results obtained were sufficient to warrant the conclusions arrived at by the authors. The variations in the silicons of the bath samples were so small that one might reasonably doubt whether they were really due to the causes assigned, or to: (1) The non-uniformity of the bath. A 25-ton bath of liquid metal was not a homogeneous mass, and he had found samples taken simultaneously from different parts of the bath to vary—especially in silicon contents; in some extreme cases the silicon being nearly twice as high in one part as in another. (2) Intermixed slag. No doubt every precaution was exercised in sampling, but if taken in the usual manner by dipping a sample spoon through the slag into the metal underneath, it was a difficult matter to obtain a sample altogether free from slag. (3) A combination of 1 and 2. If by the statement, "This with other results from the experiment, bearing out the general trend of trials made with other ends in view, and hence not followed out in detail at the time, was useful in the making of certain special steels for commercial purposes," the authors referred to the manufacture of high silicon steel, he would remind them of the well-known fact that the influence of silicon left in, or unremoved from, steel was much more injurious than that of the same amount of added silicon. From the fact that the silicon was eliminated from the bath and went to slag, and, under the special conditions of working, again entered the metal, it might be argued that the silicon was added. Granting this, it remained to be proved whether silicon thus "added" behaved in any way differently to silicon left in, as generally understood, in the metal.

Mr. E. H. **Saniter** (Rotherham) could not see that the authors' contention was confirmed by their experiments, because, in Table I., red brick charge, before adding lime and ore the silicon was 0·049 per cent., and after 0·055 per cent., with a less siliceous slag. It was also interesting to note that while the addition of 1 cwt. of lime raised the lime in the slag 0·72 per cent., it raised the magnesia 1·48 per cent. Again, in regard to Table II., lime charge. Before adding the lime the silicon was 0·049 per cent., with 55·45 per cent. silica in the slag, and after adding the lime it was 0·052 per cent., with only 53·54 per cent. silica in the slag. It was to be noted that the words lime and limestone appeared to be used indiscriminately. The same peculiarity was to be observed with the magnesia charge, Table III. Before adding the magnesia the silicon was 0·034 per cent. silicon, with 55·72 per cent. silica in the slag, while after it was 0·037 per cent., with only 54·03 per cent. silica. These differences in silicon were very small to argue about, but such as they were, they were directly opposed to the authors' contention. In conclusion, he thought that the addition of 8 cwt. of red bricks, which would float about in the slag, and be rapidly melted by the gas, would practically have no cooling effect on a 25-ton bath of steel. He suggested that the experiment be repeated, with the addition of 8 cwt. of heavy steel scrap low in silicon, which would reduce the temperature of the 25 tons of molten steel about 30 degrees centigrade.

Messrs. McWILLIAM and HATFIELD, in replying, expressed their indebtedness to Messrs. J. J. Morgan and E. H. Saniter for their courteous criticisms, as they were always much interested in the opinions of others on any open-hearth research work. Although Mr. Morgan was quite correct in saying that the differences in silicon were small, they could not agree that they might be due to inclusions of slag or errors in sampling owing (1) to the care with which the samples were taken, and (2) to the similarity in the trend of results in former cases where many experiments were made on one particular line. Had Mr. Morgan's last two sentences formed part of a paper instead of a criticism they would have called for proof of his alleged well-known fact that silicon left in was more injurious than silicon added to the metal in the ordinary way. In Mr. Saniter's criticism there were some mis-statements, a misunderstanding and an opinion differing from that of the authors. In the red brick charge there was no 0·055 silicon, and if the 0·053 silicon was meant the composition of the corresponding slag was not given, and with regard to the real point which seemed to be troubling him, if he remembered this action of a slag was not instantaneous (the rate under defined conditions was shown in former work), the matter would be quite clear to him. The manganese was not shown as increased by the addition of lime, as he stated. Mr. Saniter's remarks on the lime and magnesia charges were curious, as he disagreed with what was not stated, and pointed out something that was fully dealt with in the paper on p. 213. Few practical men connected with acid Siemens work would agree that 8 cwts. of cold red brick would not cool even a 25-ton charge, and as the authors had fully convinced themselves on the matter referred to, they did not propose to try the suggested experiment.

In conclusion, for the sake of students, the authors would point out that their 1902 paper should be read before this one, that their opinions on the influence of the basicity of a normal type of slag on the silicon content of the steel were the result of very many experiments; that the numerical results on lime slags were from one special heat only, but were in accord with certain single tests made before; and that the magnesia and manganese dioxide results, though obtained from only one special heat each, illustrated points of theoretical interest which would be appreciated by any careful thinker.

COMPARISON OF METHODS FOR THE DETERMINATION OF CARBON AND PHOSPHORUS IN STEEL.

By Baron JÜPTNER von JONSTORFF (Austria), ANDREW A. BLAIR (United States), GUNNAR DILLNER (Sweden), and J. E. STEAD, F.R.S., Member of Council (England).

INTRODUCTION.

It is a well-known fact that the results of different analysts, when operating on the same identical sample of steel or iron, are far from concordant, and it not infrequently happens that great annoyance and trouble in the commercial community are occasioned by these discrepancies.

Attempts have been made at various times to investigate the causes of such differences and to obtain more reliable methods of analysis. The most important of these was made by the British Association in 1889. The following gentlemen with Sir W. Roberts-Austen as Chairman, and Professor T. Turner as Secretary, were constituted as a committee to investigate the question, viz.: Sir F. A. Abel, Mr. Edward Riley, Mr. G. J. Snelus, Mr. John Spiller, Professor J. W. Langley, and Professor Tilden.

Average samples of steel were prepared in America under the superintendence of Professor J. W. Langley. The steels, in the form of turnings, were divided and distributed to sub-committees in Great Britain, America, France, Germany, and Sweden.

In Sweden Professor Åkerman acted as Secretary to the Swedish committee. The Government Department of Tests was appointed in Germany; Mr. Ferd. Gautier in France; the British Association Committee in England; Messrs. William Metcalf, Thomas Rod, A. E. Hunt, and Professors J. W. Langley, A. B. Prescott, and M. E. Cooley in America.

The material was furnished gratuitously by the Crescent Steelworks, Pittsburg. The ingots were made of crucible steel, excepting No. 4 standard, with 0·15 per cent. carbon, which was of open-hearth material. All the samples were turned down and about 50 lbs. of turnings from each sample were obtained.

No. 4 standard was from a rolled billet. Nos. 1, 2, and 3 standards were from unworked crucible ingots.

Portions of each were sent to the several committees and tested by the appointed analysts. It is to be regretted that neither the German nor French committees sent in any results. The Swedish, American, and English committees took an active interest in the work, and analyses were sent in to the British Association Committee, who published no less than six reports. The importance of the work done has unfortunately not been fully recognised, and little is really known of what was done by other people apart from the members of the committees. Members of the Iron and Steel Institute who are interested in the subject should remember that samples of the standard steels can still be obtained from Professor Thomas Turner, the University, Birmingham, together with the reports of the various committees.

The analysts appointed in England consisted of the following gentlemen, viz.: Mr. A. H. Allen (Sheffield), Mr. W. Jenkins (Dowlais), Mr. G. S. Packer (Glasgow), Mr. J. Pattinson (Newcastle-on-Tyne), Mr. E. Riley (London), Mr. J. E. Stead (Middlesbrough), and the Royal School of Mines, London.

The mean results of the three committees, already mentioned, are as follows, viz.:—

Mean Results of the Analyses by the Swedish Committee.

Standard.	No. 1.	No. 2.	No. 3.	No. 4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	1·450	0·840	0·500	0·170
Silicon	0·357	0·185	0·150	0·015
Sulphur	0·008	0·004	0·006	0·048
Phosphorus . . .	0·022	0·015	0·021	0·102
Manganese . . .	0·282	0·145	0·170	0·130

Mean Results of the Analyses by the American Committee.

Standard.	No. 1.	No. 2.	No. 3.	No. 4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	1·44	0·80	0·454	0·18
Silicon	0·270	0·202	0·152	0·015
Sulphur	0·004	0·004	0·004	0·038
Phosphorus	0·016	0·010	0·015	0·088
Manganese	0·254	0·124	0·140	0·098

Mean Results of the Analyses by the British Committee.

Standard.	No. 1.	No. 2.	No. 3.	No. 4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Carbon	1·414	0·816	0·476	0·151
Silicon	0·263	0·191	0·141	0·008
Sulphur, not more than . .	0·006	0·007	0·008	0·039
Phosphorus	0·018	0·014	0·021	0·078
Manganese	0·259	0·141	0·145	0·130

Mean of all the Samples.

	Swedish.	American.	English.
	Per Cent.	Per Cent.	Per Cent.
Carbon	0·740	0·715	0·714
Silicon	0·150	0·160	0·153
Sulphur	0·0165	0·0145	0·017
Phosphorus	0·040	0·032	0·033
Manganese	0·182	0·154	0·169

The only difference of any moment here shown is in the carbon, which, in the Swedish analyses, is about 0·025 per cent. higher than the American and English.

The higher phosphorus shown by the Swedish analyses is due to a very high phosphorus in No. 4 sample. The other analyses closely agree with those of the English and American analysts. Possibly the higher phosphorus in No. 4 may have been due to variations in the sample, which was obtained from a large open-hearth ingot after rolling to a billet.

At the autumn meeting of the Iron and Steel Institute held in Glasgow in 1901, a paper was read by Mr. Axel Wahlberg (Stockholm), on the variations of carbon and phosphorus in steel billets. A number of analytical tests were given which were obtained by testing identical samples of steel by several analysts in Sweden; at the testing laboratory of the Royal Technical University of Stockholm, by Mr. Gunnar Dillner, and by experts in the Hammarström Laboratory at Kopparberg, in Vienna by Baron Jüptner von Jonstorff, and in England by Mr. J. E. Stead at Middlesbrough. The report gave a full account of the results obtained by the several analytical authorities. On comparing the results there appeared to be rather a striking lack of uniformity beyond what might have been expected, caused presumably by the imperfections of some of the methods of analysis employed. It was suggested by Mr. Wahlberg that it was desirable that a standard international analytical method should be recognised by the Iron and Steel Institute.

In the course of the subsequent discussion it was then suggested by Mr. J. E. Stead that on account of the differences in the results there seemed to be some necessity for further research, and proposed that the same analytical authorities should be constituted as a committee, who should make further investigations, exchange their methods of analysis, and endeavour, if possible, to find out which was the best and most reliable.

The proposal was adopted, and the committee was formed consisting of the proposer of the resolution, together with Baron Jüptner von Jonstorff and Mr. Dillner as members. Subsequently Mr. Andrew A. Blair, representing America, was also appointed a member of the same body.

PROGRAMME OF THE PRESENT RESEARCHES.

Conforming to proposals made, homogeneous samples of borings were taken from the lower ends of ingots containing respectively about 0·1 per cent., 0·5 per cent., 1·0 per cent., and 1·5 per cent. of carbon. Samples of each steel were then distributed to the respective analysts. Each member of the committee was asked to test his samples by his own approved method, and also by the methods employed by the other analysts.

To the courtesy of the Fagersta Steelworks the committee is indebted for the material required for the analyses—namely, four square bars of acid open-hearth steel containing about the necessary amount of carbon.

Instead of making a general report, it has been considered desirable that the remarks of each member of the committee should be independent, and a review or summary of the results given at the close of the papers.

METHOD FOR THE DETERMINATION OF CARBON.

By Baron H. von JÜPTNER.

Weigh off 1 to 5 grammes according to the percentage of carbon. The turnings are treated with 150 to 300 cubic centimetres of neutral solution of copper ammonium chloride and are dissolved in the cold with continual shaking. If, when this is in progress, basic salts separate out, hydrochloric acid is added drop by drop. The solution is filtered through asbestos which has previously been ignited and washed free from chlorine. The asbestos is placed with the carbonaceous residue in a test-tube with a cooling tube inserted, the apparatus is tested to see if it is air-tight, then the air contained in the apparatus is sucked out (whereby the current of air passes through sulphuric acid and soda-lime). Next 20 cubic centimetres of chromic acid solution and 100 cubic centimetres of sulphuric acid are introduced into the apparatus and the liquid is boiled until no more carbonic anhydride is given off. Air is then drawn through the apparatus, and the U-tube with soda-lime, and finally the accompanied calcium chloride tube, are weighed. The increase of weight multiplied by 0·2727 equals the carbon.

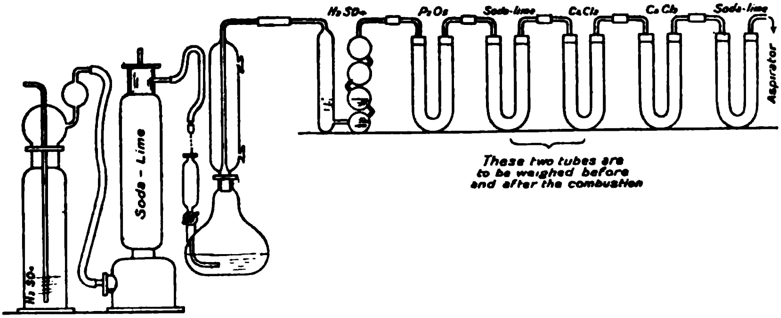

Fig. 1.

REMARKS.

Copper ammonium chloride solution: 300 grammes of copper ammonium chloride to 1000 cubic centimetres of water.

Chromic acid solution: 2 : 1. It is prepared with 10 cubic centimetres of sulphuric acid to 1 litre, and boiled.

Sulphuric acid: 2 : 1. It is saturated with chromic acid and boiled.

The apparatus is illustrated in the above figure.

METHOD FOR THE DETERMINATION OF PHOSPHORUS.

By Baron H. von JÜPTNER.

Two grammes of steel are dissolved in 60 cubic centimetres nitric acid (1·2 specific gravity) oxidised with a sufficient quantity of potassium permanganate ($K_2Mn_2O_8$) (moderately concentrated solution) boiled for at least ten minutes, the manganese dioxide dissolved with a little tartaric acid rendered alkaline by ammonia then weakly acidified by nitric acid. After cooling, 50 cubic centimetres of molybdenum solution are added, and at a temperature of 50° C. it is allowed to settle (in the water-bath), filtered and well washed with ammonium nitrate and nitric acid. The precipitate is dissolved off the filter with ammonia, evaporated in a platinum dish (and, if necessary, again filtered), acidified with nitric acid, evaporated to dryness, ignited and weighed. Factor, 0·0163.

Potassium permanganate ($K_2Mn_2O_8$).—Fairly concentrated solution.

Tartaric acid.—Fairly concentrated solution.

Molybdenum solution.—320 grammes molybdenum acid, 450 cubic centimetres ammonia, 1050 cubic centimetres water, and 4800 cubic centimetres nitric acid (1·2 specific gravity).

Washing liquid.—20 grammes ammonium nitrate, 100 cubic centimetres of water, and 10 cubic centimetres concentrated nitric acid.

REPORT BY BARON H. von JÜPTNER.

A.—Carbon Determinations.

These were carried out in the following manner :—

(*a*) The steel drillings were dissolved in 50 to 75 cubic centimetres of copper sulphate solution (40 grammes $CuSO_4$ in 100 cubic centimetres of water). To this was added 100 cubic centimetres of concentrated chromic acid and 100 cubic centimetres of sulphuric acid (1 : 1), and the carbon was then oxidised. The apparatus employed for this purpose was the ordinary Corleis apparatus.

The gases were passed (1) through a cooler, (2) through a combustion tube with platinum quartz (the layers being 15 centimetres long)—this latter operation was in accordance with the suggestion of my assistant, Mr. A. Wagner—(3) through a calcium chloride tube, (4) through a potash apparatus. (5) They were dried near the aspirator with sulphuric acid. The air drawn through was sucked through a system of soda-lime tubes.

(*b*) The arrangement of the apparatus and the procedure are similar to the above, only that instead of the calcium chloride tube (*a*, 3), a Schmitz U-tube with meta-phosphoric acid and sulphuric acid is inserted.

(*c*) The steel drillings were dissolved in 250 cubic centimetres of a solution of copper chloride and potassium chloride ($CuCl_2 + KCl$) (160 grammes copper chloride, 90 grammes of potassium chloride, and 40 cubic centimetres of hydrochloric acid to 1 litre of water), the separated carbon was filtered over asbestos, freed from acid by washing with dilute hydrochloric acid and then with water, dried and burnt in a platinum boat in the combustion tube in a current of oxygen.

The gases of combustion were passed (1) through a U-tube with copper chloride in the one leg and with potassium bichromate, moistened with a few drops of sulphuric acid, in the other leg; (3) and (4) through two calcium chloride tubes; (5) and (6) through two soda-lime tubes; (7) through a safety tube.

(*d*) The method was the same as that described under (*c*), with the exception that the dissolving was effected in a solution of neutral copper-potassium chloride.

B.—PHOSPHORUS DETERMINATIONS.

(*a*) The sample, after roasting and dissolving in nitric acid, was dissolved with hydrochloric acid. This was displaced by nitric acid, the silica was filtered off, and the phosphoric acid in the filtrate was precipitated with molybdenum solution, with the addition of ammonium nitrate. After standing for six hours in a temperature of 40° to 50° C. the precipitate was collected upon a weighed filter which had been dried at 110°, and was washed with water containing ammonium nitrate, slightly acidulated with nitric acid. Finally it was dried at 110° and weighed.

(*b*) The method is the same as that described under (*a*), except that the precipitate was dissolved in ammonium hydrate evaporated in a weighed crucible, acidulated with a small quantity of nitric acid, dried and weighed.

TABLE I.—RESULTS OBTAINED BY BARON H. VON JÜPTNER.

Carbon Determinations.

Method Employed.	H. 971.	M. 76.	H. 739.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
A (*a*)	1·570	1·105	0·459	0·141
A (*b*)	1·520	1·071	0·439	0·0936
A (*c*)	1·439	1·046	0·424	0·140
A (*d*)	1·450	1·068	0·459	0·142
Phosphorus Determinations.				
B (*a*)	0·032	0·034	0·028	0·028
B (*b*)	0·029	0·030	0·025	0·026

METHOD FOR THE DETERMINATION OF CARBON.

BY ANDREW A. BLAIR.

Place 1 gramme of pig iron, spiegel, or ferro-manganese in a 400 cubic centimetre Griffin's beaker, and add 100 cubic centimetres of a saturated solution of potassium-cupric chloride and 7·5 cubic centimetres hydrochloric acid. For steel or puddled iron, use 3 grammes and add 200 cubic centimetres of potassium-cupric chloride solution and 15 cubic centimetres strong hydrochloric acid. Stir the solution constantly with a glass rod for some minutes at the ordinary temperature. The more it is stirred the more rapid will be the solution of the iron and of the precipitated copper. The beaker, carefully covered, may now be placed on the top of the air-bath or on a cool part of the sand-bath, but the solution should never be heated hotter than 60° or 70° C., and it should be stirred as often as practicable.

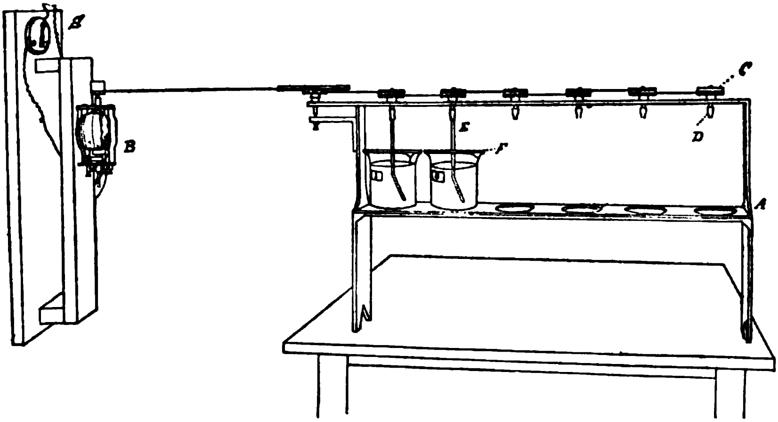

Fig. 2.

As the most tedious part of the determination of carbon in steel is frequently that which has to do with the decomposition of the steel and the solution of the precipitated copper, particularly in the case of low steels, the samples being nearly always in lumps, and it not being desirable to separate these larger particles for fear that the fine stuff alone may not represent a true average, the machine shown in Fig. 2 is very useful.

It consists of a framework, A, of brass, cast in one piece for the sake of rigidity. It is fastened to the table by lugs and screws not shown in the cut. The shelf on which the beakers stand has on it a piece of asbestos board with holes to fit exactly the bottoms of the beakers to prevent them from moving. To further increase the stability of the beakers (which should be of very heavy glass) their bottoms are ground on a glass plate with fine emery until they have a good bearing surface all around.

The tops, which are covered when on the machine with a plate of glass, F, ground on one side and perforated to allow the passage of the stirring rods E, are likewise ground, so that when slightly moistened the ground glass prevents almost entirely all movement of the covers on the beakers when the machine is in motion.

The small wooden pulleys, C, are fitted with brass spindles, which run through the upper cross-piece, and have on their lower ends pieces of rubber tubing, which serve to hold the stirring rods. The stirring rods are bent, as shown in the cut, to give the proper motion to the liquid. A small motor, B, adapted to the strength of the current, furnishes the requisite power. The motor, if properly wound, may be attached to an ordinary incandescent lighting current, but a sewing-machine motor run by a dipping battery of three bichromate cells is sufficient to give the necessary number of revolutions.

The fact that it is not only unnecessary to use a neutral solution, but that the use of a neutral solution gives inaccurate results, seems now to be thoroughly established by the experiments of the American members of the International Steel Standards Committee. The best practice is to add about 10 per cent. of hydrochloric acid to the solution of the potassium-cupric chloride. The reactions occurring may be considered as $Fe + CuCl_2 = FeCl_2 + Cu$ and $Cu + CuCl_2 = 2CuCl$. The part taken by the potassium chloride does not seem very clear, but the fact remains that the precipitated copper is much more soluble in the double salt than in any other menstrum. When the precipitated copper is all, or very nearly all, dissolved, which is usually the case in half-an-hour after the solution of potassium-cupric chloride is added to the drillings, run a little of the acidulated double chloride around the sides of the beaker by means of the rod, wash the rod over the beaker with a jet of water, and let the beaker stand for a few minutes to allow the carbonaceous matter to settle. The best form of filtering-apparatus is shown in the annexed sketches. It consists of the perforated platinum boat (Fig. 3), which fits in the platinum holder. To prepare the boat for use, place it in the holder, as shown in Fig. 4, attach the pump, but do not start it. Fill the boat with prepared asbestos suspended in water, pour enough around the outside of the boat to fill the space *a*, Fig. 4, and start the filter-pump. Continue pouring the suspended asbestos into the space *a*, Fig. 4, until enough is drawn into the joint to make a good packing. By pressing it in all around with a spatula the joint may be made very tight. Pour enough of the suspended asbestos into the boat to make a good, thick felt, and press it down firmly all over the bottom of the boat with something like the square end of a lead pencil, to make it compact. Detach the pump, remove the boat from the holder carefully so as to leave the packing on the sides of the holder, and move it up with the end of a spatula, so that it will remain as shown in Fig. 3. Place another boat in the holder, press the packing into the joint *a*, Fig. 4, with the end of a spatula, fill the boat with suspended asbestos, and start the pump. If necessary, pour a little of the finer suspended asbestos fibre into the joint to make it perfectly tight, and prepare the felt in the boat as before. Dry the boats, and ignite

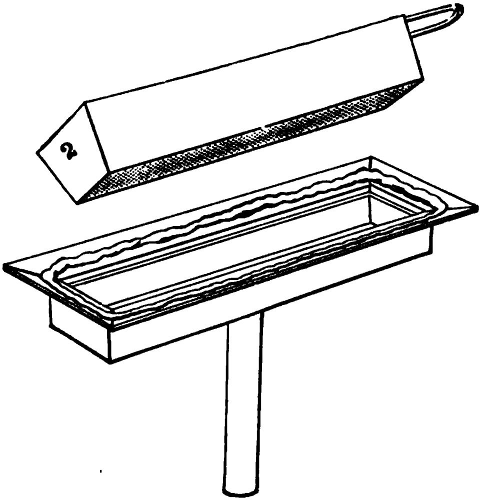

FIG. 3.

them in the combustion tube, two at a time, in a current of oxygen. Fit one of these prepared boats in the holder, press the packing into the joint as before, first moistening it slightly if it has become dry, start the pump, and pour into the boat enough suspended asbestos, which has been ignited * in oxygen, to form a thin film on the top of the felt. This film will hold the silica, ferric phosphate, &c., from the carbonaceous residue, and, after the combustion, will usually turn up at the edges, so that it can readily be detached from the main felt, leaving the boat ready for another filtration.

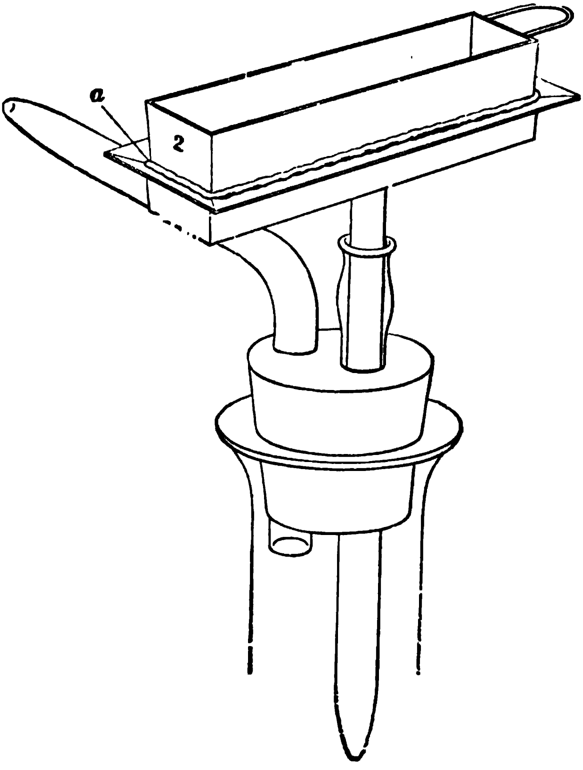

FIG. 4.

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* Barba suggests adding to the solution ignited asbestos in water to make the carbonaceous matter settle and to prevent its clogging the filter. This is a most admirable suggestion and should be generally adopted.

The boat being thus prepared, pour into it the solution of the iron or steel, guiding the stream by a small glass rod held against the tip of the beaker. The solution, if the joint *a*, Fig. 4, is tight, and the pump works well, will usually run through the felt as rapidly as it can be poured into the boat. When the supernatant fluid has all run through, transfer the carbonaceous matter to the boat by a fine stream of cold water from a washing flask. Pour into the beaker about 10 cubic centimetres of dilute hydrochloric acid, run it all around the inside of the beaker by means of the rod to dissolve any adhering salt, wash the glass rod, and wash down the sides of the beaker with a jet of water, and decant the acid into the boat, filling it almost up to the edge. Wash the carbonaceous matter in the boat thoroughly with hot water by filling the boat from the beaker and allowing it to suck through dry, but do not attempt to throw a jet of water into the boat from the washing flask, as it will be almost certain to throw some of the carbonaceous matter from the boat, or cause it to crawl over the side. In decanting the water from the beaker, the lip must not be allowed to touch the surface of the liquid in the boat, as a film of carbonaceous matter will run up the inside of the beaker. Pour a little dilute acid into the joint between the boat and the holder, allow it to suck through the packing, and wash it several times with hot water. The carbonaceous matter from pig iron, puddled iron, spiegel, ferro-manganese, and ingot steel usually washes like sand, but that from steel which has been hardened, tempered, hammered, or rolled is apt to be more or less gummy, stopping the filter and rendering the filtration and washing prolonged and tedious. It is also apt to adhere more or less to the sides of the beaker, and must be wiped off by a little wad of ignited fibrous asbestos, held in a pair of platinum-pointed forceps, like those shown in Fig. 5.

FIG. 5.

This wad is then placed in the boat. When the carbonaceous matter is thoroughly washed and sucked dry, detach the pump, remove the boat from the holder, wipe the outside carefully with a piece of silk, place it in a dish covered with a watch-glass, and dry it in a water-bath or in an air-bath at 100° C. When dry, insert the boat in the platinum tube (Fig. 7), and burn off the carbon. The rear end of the tube has a ground joint (Fig. 6), which may be made perfectly air-tight. The tube has a strengthening band of German silver at B, Fig. 7, and the part P, which is of phosphor-bronze, is ground in. To prevent the tube from sagging when it is hot, the rear end is supported at P, Fig. 7, by a wire from the top of the hood. A piece of platinum gauze ½ inch long (12 millimetres), rolled up rather loosely, fills the forward end of the tube, then the tube is filled for a distance of about 6 inches (150 millimetres) with granular copper dioxide, followed by another piece of platinum gauze of the same size as the first, and a similar roll 2 inches long, with a loop, is pushed in after the boat, the rear end coming just forward of the screen L. The limb in the U-tube G nearest the platinum tube contains anhydrous cupric sulphate, and the forward limb anhydrous cuprous chlorine. H contains dried, *not fused,* calcium chloride, and in the bulb next to G is a small wad of cotton-wool. G and H are called the purifying train, and when the apparatus is not in use they should be detached from the tube and the ends closed with pieces of glass rod. The object of the cuprous chloride is to absorb any chlorine that may come over during the combustion. If any should come over, it would be mixed with hydrochloric acid and moisture, and all then would be absorbed by the salts in the tube G. If the carbonaceous residue is properly washed it will be found necessary to renew the salts in G only after it has been used for twenty-five or thirty combustions.

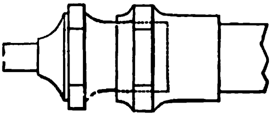

FIG. 6.

Before making a combustion, or series of combustions, the tube should be well burned out by heating it to redness, and passing a current of oxygen through the apparatus, heating the

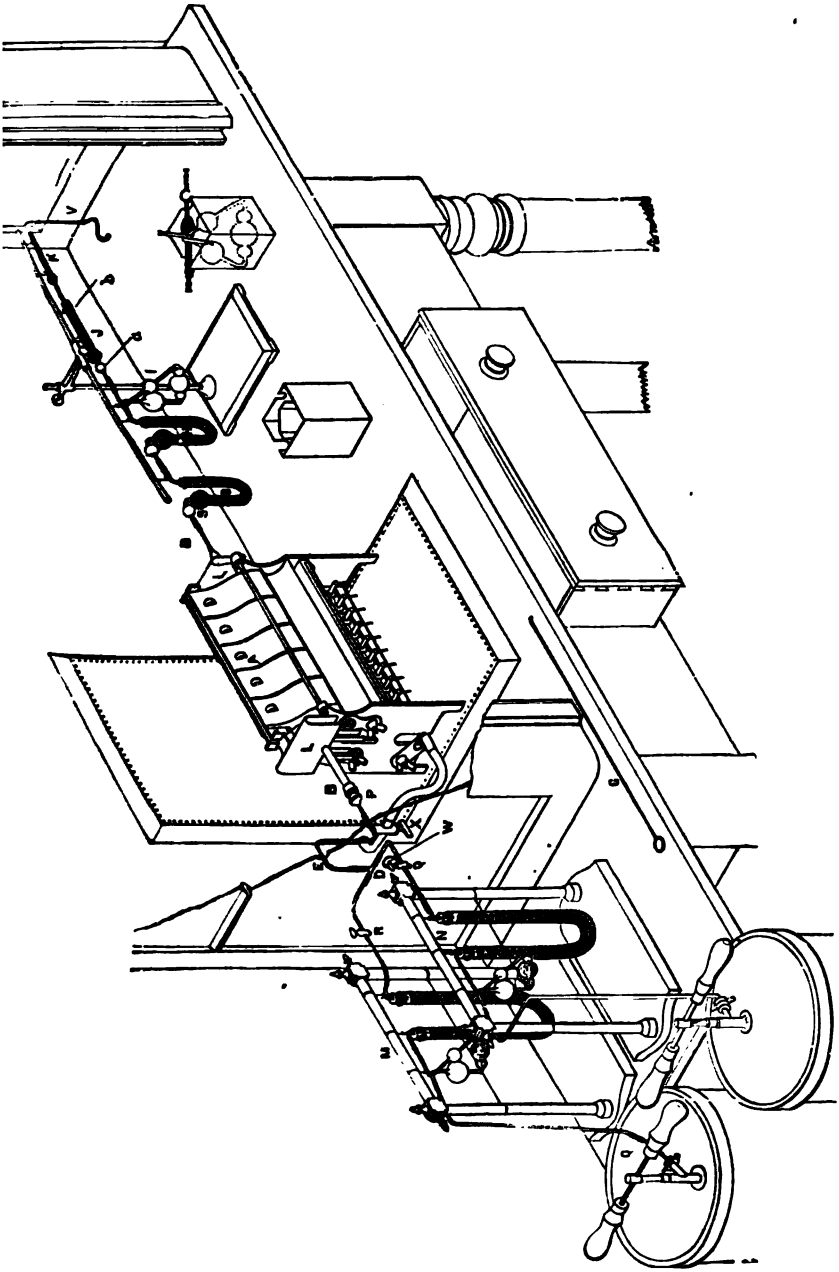

Fig. 7.

small tube S red hot at the same time by means of a small blast-lamp or Bunsen burner. During this operation fumes of sulphuric acid issue from the end of S, and usually, when the flame of the lamp is carried out to this point, it is coloured green, showing that a small amount of copper salt is also volatilised. In making a combustion the platinum should not be heated above a low red, as at a high temperature platinum becomes permeable by carbonic acid. The cylinder O contains oxygen under pressure, the other contains atmospheric air which is forced through the apparatus to replace the oxygen at the end of the operation.

The purifying apparatus M and N, for oxygen and air respectively, consist of Liebig potash bulbs filled with solution of potassium hydrate (1·27 sp. gr.), and the U-tubes, the sides next the potash-bulbs filled with dry pumice and the other sides with calcium chloride. The glass stopcocks Q and R shut off the purifying apparatus on their respective sides when the oxygen or air is passing through the other set. The T-tube D connects the two sets of apparatus, the third limb passing through the glass in the side of the hood, and connecting by means of the bent glass tubes with the rubber stopper P, which fits in the porcelain tube B. All the connections are made with glass tubes joined together by rubber tubing, the ends of the glass tubing being brought close together inside the rubber. This is to avoid carrying the oxygen or air through rubber tubing, which gives off volatile hydrocarbons. The absorption apparatus consists of the Liebig bulb I, and the drying tube J. I contains caustic potash (1·27 sp. gr.). It is filled by attaching a short piece of rubber tubing to one end and applying suction to it, the other end being immersed in the potash solution, which has been poured into a capsule. The end must be wiped dry with a little filter-paper, and the inside of the tube dried in the same way. When filled, the bulb should contain the solution as shown in Fig. 8. When attached to the apparatus, the gas passes first into the large bulb, and, the bulbs being inclined, the gas bubbles through the solution in the three bottom bulbs. It is fitted with a loop of platinum wire, as shown in Fig. 8. The drying tube J contains dried calcium chloride. The small tube *a*, Fig. 7, contains a plug of cotton-wool, and another plug of the same material is inserted after the calcium chloride at *b*. K is a safety-guard tube, to prevent moisture from getting into the tube J during the combustion. The short rubber tube V is used to draw a little air through to test the tightness of the joints. All the stoppers in the various U-tubes and drying tubes are of rubber. The copper rod C is used to introduce the boats, &c., into the tube B, running the crooked end through the hole W in the glass side of the hood. When not attached to the apparatus, the ends of the potash-bulb I and drying tube J are closed by little caps of rubber tubing (Fig. 8) made like the tips for "policemen." When on the balance, however, they should be closed with short pieces of rubber tubing containing bits of capillary glass tubing, as shown in Fig. 9. The forward end of the drying tube is closed in the same way. These openings are too small to allow the condition of the atmosphere to affect the weight of the bulbs by loss or gain of moisture, but they serve to equalise the pressure and make it unnecessary to reopen the balance-case until the bulbs are weighed.

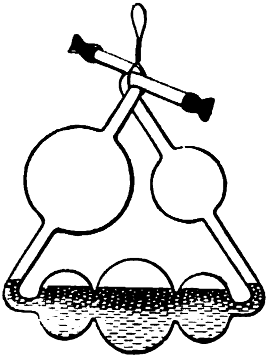

FIG. 8.

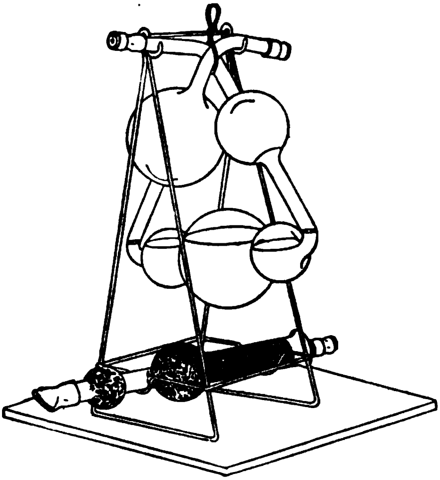

FIG. 9.

It is very necessary in filling the potash-bulb to avoid getting any of the solution on the outside of the bulb, and it is well to see that both the bulb-tube and the drying tube are perfectly clean. Wipe the potash-bulb and drying tube with a piece of linen, not silk (a clean linen handkerchief that does not leave lint on the glass is very good for this purpose), then place them on the balance.

The little wire stand shown in Fig. 9 is very convenient for holding the absorption apparatus in the balance, as it brings all the weight on the pan instead of putting the greater part on the beam alone, as is the case when the potash-bulbs are suspended from the hook on the end of the beam. Allow them to remain about thirty minutes to get the exact temperature of the balance, and weigh. Attach the absorption apparatus as shown in the sketch, Fig. 8, insert the boat in the tube by means of the rod C, pushing it up against the cupric oxide, insert a short roll of platinum gauze as far as the inside of the screen L, and close the tube with the stopper P. Shut the stopcocks R and Q, and, by applying suction at V, draw a few bubbles through the potash-bulb I. When the liquid recedes in the potash-bulb, it should keep its level for a few minutes; if it does not, there is a leak in some of the connections, which must be discovered and stopped before proceeding with the combustion. When everything is tight, open R and start a slow current of oxygen through the apparatus. Light the two forward burners of the furnace, turning them low to heat the copper oxide, raise the heat gradually until the tube appears red, and then light the last burner to heat the short roll of platinum gauze. As soon as this end of the tube is hot, light the third burner from the forward end, and a few minutes afterwards the fourth burner, which is directly under the forward end of the boat. Light each burner in succession from this one until all are lighted and turned high enough to heat the tube red hot. Allow them to burn for fifteen minutes, then shut off the oxygen, close R, open Q, and by means of the stopcock T start a current of air through the apparatus. By means of the gascock X lower all the lights of the furnace together very slowly, and finally turn them out. About 1 litre of air should run through at the rate of three bubbles a second; this will take about twenty-five minutes. Close T and Q, detach the absorption apparatus, close the ends of I and J with the little rubber caps, and, after wiping the bulb and the tube gently with the linen handkerchief to remove any moisture caused by the handling, place them on the balance. Weigh with the same precautions as before; the increase in weight is carbonic acid, which contains 27·27 per cent. carbon. When several combustions are to be made in succession, as soon as the absorption apparatus is detached as directed above, remove the boat from the tube, replace it with another containing a second sample, attach a second absorption apparatus which has just been weighed, and proceed with the combustion. While the second combustion is in progress, the first absorption apparatus may be weighed, and the weight then obtained can be used for the first weight of the absorption apparatus for a third combustion. Before the absorption apparatus shall have increased 0·5 gramme in weight from the original weighing, the potash-bulb must be emptied and refilled with a fresh solution.

METHOD FOR THE DETERMINATION OF PHOSPHORUS.

By ANDREW A. BLAIR.

This method gives an indirect determination of phosphorus by means of the estimation of the molybdic acid in the ammonium phospho-molybdate, in which form the phosphorus is precipitated. The molybdic acid is reduced to a lower state of oxidation by the reducing action of zinc and sulphuric acid, and the reduced oxide is titrated with a standardised permanganate solution, molybdic acid being again formed by the reaction.

Fig. 10 shows a form of shaking-machine for shaking four flasks at once. The construction and method of use are apparent from the sketch.

Fig. 11 shows a form of reductor which is most convenient and efficient. The tube *a* is 0·018 metre inside diameter and 0·300 metre long. The small tube below the contraction with the stopcock *c* is 0·006 metre in inside diameter and 0·300 metre long below the stopcock. The tube is filled by placing at the point of contraction a flat place of fine platinum gauze. On top of this is placed a plug of glass wool, about 8 millimetres thick, and then asbestos, previously treated with concentrated hydrochloric acid, thoroughly washed, ignited, and diffused in water, is poured into the reductor tube until it forms a coating on top of the glass wool not over 1 millimetre thick. This makes a filter which prevents very small pieces of zinc or other materials from being carried through. It is necessary to clean and refill the tube from time to time, as the filter after some use becomes clogged and the liquid passes too slowly. The tube is filled, as shown in the cut, with granulated amalgamated zinc. The reductor tube is fixed at such a height that when the block is removed from under the flask *f*, the latter may readily be detached from the tube and removed without disturbing the apparatus.

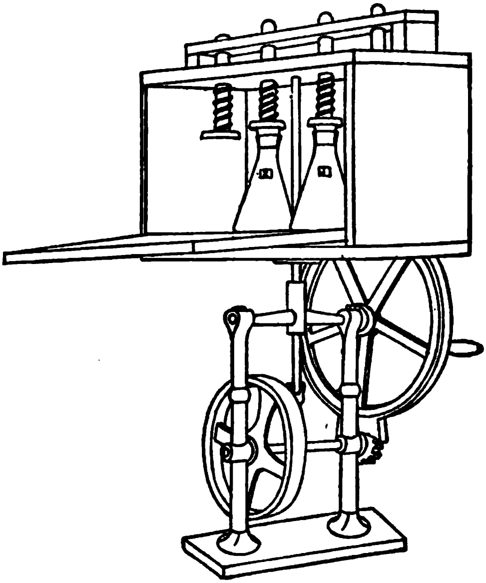

FIG. 10.

REAGENTS.

Nitric Acid.—Nitric acid of 1·135 sp. gr., made by mixing chemically pure nitric acid (1·42 sp. gr.) with about three parts of distilled water.

Strong Sulphuric Acid.—The chemically pure material of 1·84 sp. gr.

Dilute Sulphuric Acid.—Sulphuric acid 2½ per cent., by volume, made by diluting 25 cubic centimetres of concentrated chemically pure sulphuric acid to 1 litre with distilled water.

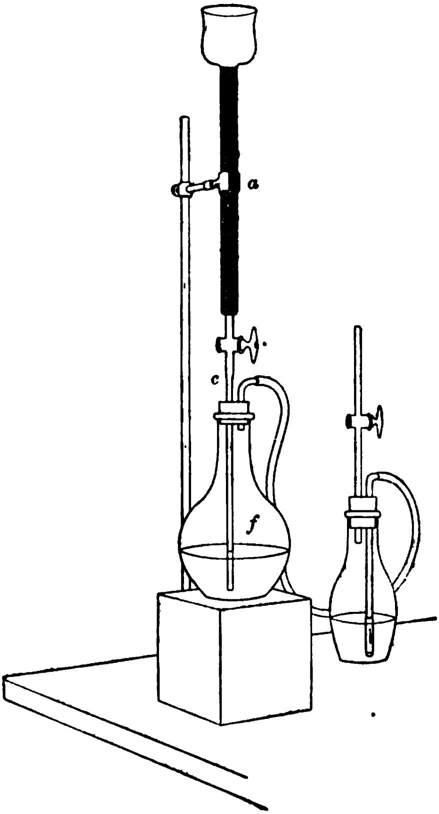

FIG. 11.

Strong Ammonia.—The chemically pure material of 0·90 sp. gr.

Dilute Ammonia (0·96 sp. gr.).—Made by mixing concentrated chemically pure ammonia water of 0·90 sp. gr. with about one and one-half times its volume of distilled water.

Strong Solution of Potassium Permanganate.—For oxidising the phosphorus and carbonaceous matter in the nitric acid solution of a steel. Made by dissolving from 12·5 to 15 grammes of crystallised potassium permanganate in 1 litre of distilled water and filtering through asbestos.

Standard Solution of Potassium Permanganate.—For titrating the reduced solutions of ammonium phospho-molybdate. Made by dissolving 2 grammes of crystallised potassium permanganate in 1 litre of distilled water and filtering through asbestos. This solution is standardised as follows: Place from 0·15 to 0·25 gramme of thoroughly cleaned soft steel wire, in which the iron has been carefully determined, in each of three 125 cubic centimetres Erlenmeyer flasks, and pour into each of the flasks 30 cubic centimetres of distilled water and 10 cubic centimetres of strong sulphuric acid. Cover with a small watch-glass and heat until solution is complete. Add a sufficient amount of the strong solution of potassium permanganate to oxidise the iron and destroy the carbonaceous matter, being careful to avoid an excess which would cause a precipitate of manganese dioxide. Should this occur, redissolve it by adding a very few drops of sulphurous acid and boil off every trace of the latter. Allow the solution in the flasks to cool and add to each 10 cubic centimetres of dilute ammonia. Pass through the reductor and titrate in the flask.

In all cases the mode of procedure in using the reductor should be as follows: Everything being clean and in good order from previous treatment with dilute sulphuric acid, and washing with distilled water, and the flask being attached to the filter-pump, pour 100 cubic centimetres of warm dilute sulphuric acid into the funnel and open the stopcock *c*. When only a little remains in the funnel forming the top of the reduction tube, transfer the solution to be reduced to the funnel. This solution should be hot, but not boiling. Pour some of the dilute sulphuric acid into the vessel which contained the solution to be reduced to wash it, and when only a little solution is left in the funnel as before, add this to the funnel in such a way as to wash it, and follow with about 200 cubic centimetres more of warm dilute sulphuric acid, and finally with 50 cubic centimetres of hot distilled water. In no case allow the funnel to get empty, and close the stopcock *c* when there is still a little of the wash-water left in the funnel above the surface of the zinc. This precaution prevents air from passing into the reductor tube. A blank determination is made by passing through the reductor a solution containing a mixture of 10 cubic centimetres strong sulphuric acid, 10 cubic centimetres dilute ammonia, and 50 cubic centimetres water, preceded and followed by the dilute acid as described above. The amount of potassium permanganate required to give this blank a distinct colour is subtracted from the amount required to give the same colour to each reduced solution.

To get the value of the permanganate solution, multiply the weight of iron wire taken by the percentage of iron in the wire and divide by the number of cubic centimetres of potassium permanganate in terms of metallic iron. Multiply this result by 0·88163, the ratio of molybdic acid to iron, and the product by 0·01794, the ratio of phosphorus to molybdic acid, and the result is the value of 1 cubic centimetre of the permanganate solution in terms of phosphorus. The ratio of molybdic acid to iron given above is that found when a known amount of molybdic acid in sulphuric acid solution is passed through the reductor in the manner described above, and then titrated with potassium permanganate solution whose strength in terms of metallic iron is known. The reduction of the molybdic acid in the reductor in this case is to the form $Mo_{24}O_{37}$. The ratio of phosphorus to molybdic acid given above is that found by the analysis of the yellow precipitate of ammonium phospho-molybdate obtained from nitric acid solution of iron under varying conditions.

Sulphurous Acid.—A strong solution of the gas in water. Siphons of the liquefied gas may be obtained in the market.

Acid Ammonium Sulphite.—The strong chemically pure solution of the reagent diluted with ten parts of water.

Ferrous Sulphate.—Crystals of the salt free from phosphorus.

Sodium Thiosulphate.—Crystals of the salt free from phosphorus.

These four reagents are for reducing the excess of binoxide of manganese thrown down in oxidising the carbonaceous matter in the nitric acid solutions of the steels. Any one may be used.

Molybdate Solution.—Place in a beaker 100 grammes of pure molybdic anhydride, mix it thoroughly with 400 cubic centimetres cold distilled water and add 80 cubic centimetres strong ammonia (0·90 sp. gr.). When solution is complete, filter and pour the filtered solution slowly and with constant stirring into a mixture of 400 cubic centimetres strong nitric acid (1·42 sp. gr.), and 600 cubic centimetres distilled water. Add 50 milligrammes of microcosmic salt dissolved in a little water, agitate thoroughly, allow the precipitate to settle for twenty-four hours, and filter before using.

Acid Ammonium Sulphate Solution.—For washing the precipitate of ammonium phospho-molybdate. To 1 litre of water add 15 cubic centimetres of strong ammonia (0·90 sp. gr.) and 25 cubic centimetres strong sulphuric acid (1·84 sp. gr.).

Amalgamated Zinc.—Dissolve 5 grammes of mercury in 25 cubic centimetres strong nitric acid diluted with an equal bulk of water, dilute to 250 cubic centimetres and transfer to a stout flask of about 1000 cubic centimetres capacity. Pour into it 500 grammes of granulated zinc which will pass through a 20-mesh sieve, but not through a 30-mesh. Shake it thoroughly for a minute or two and then pour off the solution, wash the zinc thoroughly with distilled water, dry, and preserve in a glass bottle for use.

OPERATION.

Weigh 2 grammes, or, in case of steels containing over 0·15 per cent. phosphorus, 1 gramme of the drillings and transfer them to a 250 cubic centimetre Erlenmeyer flask, pour into the flask 100 cubic centimetres of nitric acid (1·135 sp. gr.) and cover with a small watch-glass. Heat until the solution is complete and nitric oxide is boiled off. Add 10 cubic centimetres of the strong potassium permanganate solution, boil until the pink colour has disappeared and manganese dioxide separates. Continue the boiling for several minutes, then remove from the source of heat and add a few drops of sulphurous acid, a small crystal of ferrous sulphate, or a solution of 0·5 gramme of sodium hyposulphite in 10 cubic centimetres of water, repeating the addition at short intervals until the precipitated manganese dioxide is dissolved. Boil two minutes longer, place the flask in a vessel of cold water, or allow it to stand in the air until it feels cool to the hand, and then pour in 40 cubic centimetres of dilute ammonia (0·96 sp. gr.).

The precipitated ferric hydrate will redissolve when the liquid is thoroughly mixed. When the solution is about the temperature of the hand, say 35° C., add 40 cubic centimetres of molybdate solution at the ordinary temperature, close the flask with a rubber stopper, and shake it for five minutes, either by the hand or in the machine, Fig. 10. Allow the precipitate to settle for a few minutes, filter on a 0·090 millimetre filter, and wash with acid ammonium sulphate solution until 2 or 3 cubic centimetres of the wash-water give no reaction for molybdenum with a drop of ammonium sulphide. Pour 5 cubic centimetres of ammonia (0·90 sp. gr.) and 20 cubic centimetres of water into the flask to dissolve any adhering ammonium phospho-molybdate and then pour it on the precipitate in the filter, allowing the filtrate to run into a 250 cubic centimetre Griffin beaker. Wash out the flask and wash the filter with water until the solution measures about 60 cubic centimetres. Add to the liquid in the beaker 10 cubic centimetres strong sulphuric acid and pass it through the reductor exactly in the manner described for the solution of ferric sulphate in standardising the solution of potassium permanganate, being careful to keep the end of the small tube of the reductor just below the surface of the liquid in the flask. By adding the strong sulphuric acid to the ammoniacal solution immediately before passing it through the reductor it is heated sufficiently by the chemical action to insure thorough reduction. In washing be careful that no air passes into the reductor, and when the water has been drawn through, leaving a little still remaining in the funnel, close the stopcock, detach the flask F, wash off the drawn-out portion of the reductor tube into it, and titrate the solution with the standard permanganate. The reductor should be so arranged that the whole reduction occupies about three or four minutes. The solution that passes through should be bright green in colour. In adding the permanganate, the green colour disappears first, and the solution becomes brown, then pinkish yellow, and ultimately colourless. Continue the addition of the permanganate drop by drop, shaking the flask vigorously until the solution assumes a faint pink coloration, which remains after standing one minute. Subtract from the reading of the burette the amount given by a blank determination, obtained exactly as described under the method given above for standardising the permanganate solution, multiply the number of cubic centimetres so obtained by the value of 1 cubic centimetre in terms of phosphorus, multiply by 100 and divide by the weight taken, and the result is the percentage of phosphorus in steel.

EXAMPLE.

0·1745 gramme of wire requires 50 cubic centimetres of permanganate to give the required colour. A blank determination gave 0·1 cubic centimetre, so that the wire actually required 49·9 cubic centimetres permanganate. The wire contained 99·87 per cent. of iron, then $0·1745 \times 0·9987 \div 49·9 = 0·0034923$, or 1 cubic centimetre of permanganate equals 0·0034923 gramme metallic iron. Then multiplying the value in iron by the ratio of molybdic acid to iron 0·88163 or 0·85714 and the product by the ratio of phosphorus to molybdic acid 0·01794, we have $0·0034923 \times 0·88163 \times 0·01794 = 0·000055238$, or 1 cubic centimetre permanganate = 0·000055238 gramme of phosphorus. Again, the precipitated ammonium phospho-molybdate from 2 grammes of steel required 35·6 cubic centimetres permanganate less blank 0·1 cubic centimetres = 35·5 cubic centimetres; $35·5 \times 0·000055238 \times 100 \div 2 = 0·098$ per cent. phosphorus.

NOTES AND PRECAUTIONS.

It will be observed that the method given above oxidises the phosphorus in the iron by means of nitric acid, completes and perfects this oxidation and possibly neutralises the effect of the carbon present by means of potassium permanganate, and then separates the phosphoric acid from the iron by means of molybdic acid. The molybdic acid in the yellow phospho-molybdate is subsequently determined by means of potassium permanganate, the phosphorus being determined from its relation to the molybdic acid in this precipitate. The method given above applies to steel and wrought iron, but it is not yet recommended for pig iron.

It is hardly necessary to say that all the chemicals and materials used in the analysis are assumed to be free from impurities that will injuriously affect the result.

1·135 sp. gr. nitric acid apparently oxidises the phosphorus just as successfully as a stronger one, while by its use solution is sufficiently rapid, and there is less trouble during the subsequent filtration due to silica.

The boiling of the solution to remove nitrous acid and assist the action of the oxidising permanganate seems to be essential. Some steels may not require 10 cubic centimetres of the permanganate, and some, like washed metal high in carbon, may require even more. It is essential that enough should be added to cause a precipitation of manganese dioxide and give a strong pink colour to the solution. This colour gradually disappears on boiling. Less is required if the permanganate is added in small successive portions. Boiling two minutes after reducing the manganese dioxide removes any nitrous acid that may be formed by that operation.

In washing the yellow precipitate it shows some disposition to crawl up to the top of the filter. Care should therefore be taken to have the filter fit the funnel so closely that even if the precipitate does crawl over the top it will not be lost while washing the filter completely to the top. It is very easy to leave enough molybdic acid in the top of the filter, even though the washings are tested, to cause an error of ·005 per cent. in the determination.

It is best to make up molybdate solution rather frequently. It is also best to keep it in the dark, at a temperature not above 28° or 30° C. Much of the so-called molybdic acid of the market is ammonium molybdate, or molybdate of some other alkali. This fact cannot be ignored in making up the molybdate solution. A series of experiments with various molybdic acids and alkaline molybdates obtained in the market indicates that if the amount of molybdic acid in the solution is that called for by the formula, irrespective of whether this amount is furnished by pure molybdic acid or by any of the commercial molybdates referred to, the result will be much nearer the truth than if this is not done. Good molybdic acid is the best, but the alkaline molybdates can be used. The amount of molybdic acid in these molybdates can readily be determined by dissolving 0·1000 gramme in 60 cubic centimetres of water to which 10 cubic centimetres of dilute ammonia have been added, filtering, adding 10 cubic centimetres strong chemically pure sulphuric acid, and passing through the reductor as above described. The method given in the example above enables the amount of molybdic acid to be determined. If the molybdic acid as obtained in the market, or the ammonia used in dissolving it, contains any soluble silicates, the resulting molybdate solution will be yellowish in colour, and the determination made with this solution will be high, owing apparently to ammonium silico-molybdate being dragged down with the phospho-molybdate. Treatment of the molybdate solution with microcosmic salt, as described, overcomes this difficulty and gives a perfectly colourless molybdate solution. A molybdate solution tinged with yellow should never be used. It will be observed that the molybdate solution recommended above contains much less ammonium nitrate than is given by many of the formulæ now in use. Experience shows that a molybdate solution made on this formula keeps much better than those containing more ammonium nitrate. It will also be observed that the amount used for each determination is less than many methods employ. It is believed that the amount recommended is sufficient, and that the ammonium nitrate required to assist the formation of the yellow precipitate is furnished by the 40 cubic centimetres of dilute ammonia added to the nitric acid solution of the steel. Of course the molybdate solution recommended above cannot be used for other work interchangeably with that made on the older formulæ, on account of lack of ammonium nitrate.

The directions in regard to the reductor, both as to making and use, should be strictly followed. By the use of the stop-cock and the amalgamated zinc, and by keeping a little liquid in the funnel, the same blank can be obtained from a reductor almost continuously, even though two or three days of standing intervene between the blanks. It is, however, always advisable to treat with dilute sulphuric acid and wash before using, even though only one night has elapsed since the last previous use. If the solution to be reduced does not contain enough acid or is not warm enough, the reduction will not be complete. Care should therefore be taken not to allow too much mixing of the dilute sulphuric acid with the solution to be reduced, either in the funnel or in the reductor tube itself. The best asbestos to be used is the mineral known as actinolite, but any fibrous mineral which will act as a filter and not be dissolved by the acids used may be employed. Glass wool alone will not do, as a good filter is essential in order that neither small particles of zinc nor impurities in the zinc may be drawn down into the flask with the reduced solution. The consumption of zinc is very small.

In testing the ammonium sulphide to see whether the washing of the yellow precipitate is complete, good results are obtained by putting two or three drops of yellow ammonium sulphide into a few cubic centimetres of distilled water, and allowing the washings to drop into this solution from the stem of the funnel. If iron is present in the washings it will show while the solution is still alkaline. By allowing the washings to continue running into the ammonium sulphide solution it soon becomes acid, when molybdenum, if any is present, shows by a more or less brownish colour. If the acid solution is pure white from separated sulphur, the washing is complete.

Since the acidity of the solution in which the yellow precipitate is formed has an influence on its composition, it is quite desirable that the specific gravity of the 1·135 nitric acid and of the 0·96 ammonia should be taken with some care. The temperature at which the figures are correct is 15° C. It is best to use the Westphal balance in determining these gravities, but, failing this, a sufficiently delicate hydrometer may be employed.

With the amalgamated zinc in the reductor made as above described, the blank generally uses up about 0·1 cubic centimetre of the standard permanganate solution.

If the amount of sulphurous acid or other reagent added to the nitric acid solution to remove the precipitated binoxide of manganese is insufficient, a brown stain will be left on the filter-paper after the yellow precipitate is dissolved in ammonia. This may occur even though the nitric acid solution looks clear, and as no harm can arise from a slight excess of the reducing agent, it is usually more satisfactory to add an excess. It is not desirable to add the reducing agent to the solution while boiling, as under such circumstances it frequently boils over.

It is rather essential to use the dilute sulphuric acid warm, so that the general temperature of the reductor may be kept up.

A good method for cleaning the wire in standardising the potassium permanganate is as follows: Take a round lead pencil and make a hole in it with a pin near the end. Insert the end of the wire in this hole and revolve the pencil until there are two turns of the wire around it. Hold the turns firmly in one hand and cut the wire so that about 0·75 millimetre will remain attached to the pencil. Draw this wire through a piece of folded fine sandpaper. Seize the wire near the pencil with the filter-paper and cut off the part which was wound around the pencil and remove it. Then insert the end of the cleaned wire in the hole and revolve the pencil with one hand, holding the wire in the filter-paper in the other hand, until it is all wound loosely on the pencil. Push the coiled wire off the end of the pencil. It is now in a convenient form for weighing. (This is the method adopted by the sub-committee on standards of the United States members of the International Steel Standards Committee. The sub-committee consisted of Messrs. Barba, Blair, Drown, Dudley (chairman), and Shimer. The sub-committee found by exhaustive experiments of specially prepared samples containing as much as 0·18 per cent. arsenic that no arsenic was precipitated with the phosphorus when the temperature of the solution was kept below 40° C.)

TABLE II.—RESULTS OBTAINED BY ANDREW A. BLAIR.

Carbon Determinations.

	H. 971.	M. 76.	H. 739.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Sample as received	1·414	1·040	0·434	0·098
Fine	1·421	1·039	0·451	0·105
Coarse	1·409	1·036	0·413	0·089
Average—Fine and Coarse . .	1·412	1·038	0·432	0·097

Phosphorus Determinations.

	H. 971.	M. 76.	H. 739.	L. 422.
Sample as received	0·019	0·018	0·022	0·026
Fine	0·020	0·016	0·022	0·025
Coarse	0·018	0·018	0·021	0·027
Average—Fine and Coarse . .	0·019	0·017	0·021	0·026

Under the heading, "Sample as received," are given the results of the analyses of the samples, the proper proportion of coarse and fine having been calculated with the eye. The samples were then sieved, the two portions "Fine" and "Coarse" weighed, and under the heading of "Average of Fine and Coarse" are given the results calculated from the proportion of "Fine" and "Coarse" found.

METHOD FOR THE DETERMINATION OF CARBON.

By GUNNAR DILLNER.

1. *Apparatus.*

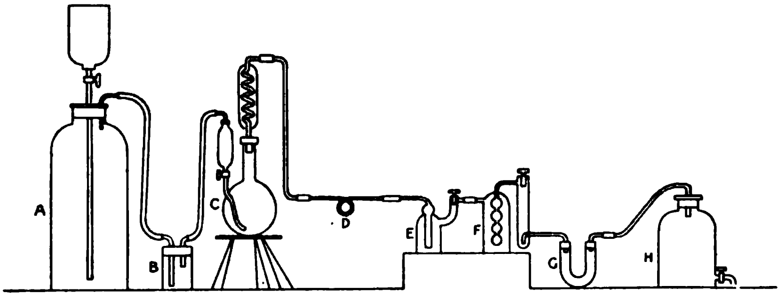

FIG. 12.

A. Air reservoir.
B. Bottle containing caustic potash (KOH) for absorbing CO_2.
C. Combustion vessel provided with a separate feeding orifice and a close-fitting condenser.
D. Platinum tube.
E. Tube fitted with anhydrous chloride of calcium ($CaCl_2$).
F. Absorption tube containing caustic potash.
G. Tube filled with anhydrous chloride of calcium ($CaCl_2$).
H. Aspirator.

2. *Principle of Method.*—The steel sample is dissolved in a solution of sulphate of copper ($CuSO_4$), and the liberated carbon oxidised by means of chromic acid (CrO_3) and sulphuric acid (H_2SO_4), and the hydrocarbons formed being burnt into carbonic acid (CO_2) and H_2O by making the gas, together with a current of air, pass through a platinum tube heated to redness. After passing from D the gas is dried by passing through a tube filled

with anhydrous chloride of calcium ($CaCl_2$), it then enters a tared absorption tube containing caustic potash (KOH), where the carbonic acid is absorbed; an additional tube with anhydrous chloride of calcium is provided for absorbing any water which may escape from the CO_2 absorption tubes.

On the other side of the absorption tubes there is another tube containing anhydrous chloride of calcium ($CaCl_2$) to prevent the passage of extraneous moisture into the absorption tubes.

3. *Manner of Procedure.*—The steel sample is put into the flask C, 1 gramme in the case of steels containing above 0·8 per cent. carbon, 3 grammes if the steel contains between 0·7 and 0·8 per cent., and 5 grammes if below 0·7 per cent. carbon. In order to expel the impure air a current of purified air is first passed from the air cylinder through the whole apparatus. From 50 to 75 cubic centimetres sulphate of copper ($CuSO_4$), according to the weight of the sample, are added through the mouth of the combustion flask C. This is slowly heated until the bulk of the iron is dissolved, and the sulphate of copper is discoloured, an operation which will take about twenty minutes. There are then added 100 cubic centimetres chromic acid (Cr_2O_3) and the same quantity of sulphuric acid (H_2SO_4). The solution is then boiled until there is no further evolution of gases. During this process a current of air is constantly passed through the apparatus in order to oxidise any hydrocarbons as they pass through the heated platinum tube. This current should give about twenty to thirty bubbles per minute when passing through the vessel B. The combustion will generally be accomplished within about forty-five minutes. In order to make certain of all the carbon being oxidised, and also to expel from the acid solution any dissolved CO_2, there are now added 2 to 3 cubic centimetres peroxide of hydrogen (H_2O_2), which causes a rapid evolution of oxygen gas. After this addition the mixture is kept boiling for ten minutes, when the test will be at an end and the absorption tube with contents ready for weighing. From the increase in weight due to CO_2 the percentage of carbon is calculated.

4. *Reagents Required.*—Concentrated solution of sulphate of copper.

Concentrated solution of chromic acid.

Sulphuric acid (1 concentrated + 1 water).

METHOD FOR THE DETERMINATION OF PHOSPHORUS.

BY GUNNAR DILLNER.

1·64 gramme of the steel is dissolved in nitric acid (HNO_3) (sp. gr. 1·22). The solution is boiled until the sample is dissolved, when it is evaporated to dryness, and then strongly heated on an iron slab for one hour, after which it is again dissolved, in hydrochloric acid (HCl), and once more evaporated to dryness, this being done in order to render the silica (SiO_2) insoluble. The residue is once more dissolved in nitric acid (HNO_3, 20 cubic centimetres), and to accelerate the process, if need be, a few drops of hydrochloric acid (HCl) added. The silica is now filtered off, and there is added to the filtrate an equal quantity of a solution of molybdate of ammonia. The beaker containing this solution is then placed into a water-bath at a temperature of 40° C., where it is left to stand for four hours in order to make the phospho-molybdate settle out. The precipitate thus obtained is then collected on a tared filter and weighed, every milligramme of the weight of the precipitate representing 0·001 per cent. phosphorus in the sample.

In order to obtain the tare and weight of the precipitate the filter is weighed at first after having been dried for one to one and a half hours in a drying oven, and then left to cool for ten minutes in a desiccator, and the same proceeding is then repeated again after filtration, the filter with the precipitate being also submitted to similar operations of drying and desiccating.

REPORT BY GUNNAR DILLNER ON THE VARIOUS ANALYTICAL METHODS.

A.—CARBON DETERMINATIONS.

The methods of estimating carbon used in this investigation can be referred to as the "direct" or "indirect." When the solution of the sample and the oxidation of the carbon takes place within the same vessel, the method is a direct one: when, on the contrary, the steel solution is filtered, and the carbon residue is burnt off in a special furnace, the process can be named an indirect one. The "Stead" direct process, as well as the "Saernstroem" method, belong to the former, whilst the "Stead" and "Blair" potash-copper process and the "Jüptner" mode of procedure are of the indirect class.

The methods employed in the following determinations were the Saernstroem for the carbon, modified in certain points by myself, and for phosphorus the Eggertz method, the details of which were rigidly adhered to.

TABLE III.—RESULTS OBTAINED BY GUNNAR DILLNER.

Carbon Determinations.

Method Employed.	H. 971.	M. 76.	H. 739.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Stead's direct process	1·49	1·01	0·45	0·10
	1·49	1·04	0·43	0·09
	1·41	1·01	0·46	0·10
	1·45	1·02	0·46	0·10
Average .	1·46	1·02	0·45	0·10
Stead's potash-copper process . .	1·41	1·02	0·36	0·12
	1·27*	0·98	0·45	0·08
	1·41	...	...	...
	1·44	...	...	...
Average .	1·42	1·00	0·41	0·10
Jüptner's method	1·30	0·96	0·40	0·09
	1·42	0·94	0·49	0·10
	1·41	...	0·42	...
	1·38	...	0·37	...
Average .	1·38	0·95	0·42	0·10
Saernstroem's method	1·43	1·00	0·43	0·09
	1·45	1·00	0·45	0·10
	1·46	1·02	0·44	0·10
Average .	1·45	1·01	0·44	0·10
Phosphorus Determinations.				
Stead's method	0·021	0·026	0·026	0·031
	0·022	0·026	0·025	0·031
Eggertz' method	0·023	0·022	0·022	0·030
	0·022	0·023	0·024	0·030

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* This was excluded in averaging the results, as combustion was probably not complete. If it is included the average is 1·42 per cent.

On examining, then, the two indirect methods, we find that they are similar, in so far as the steel is dissolved in both cases by means of a copper solution, the only difference being in detail of working. According to the "Jüptner method," solution of the steel is effected without heating, but is facilitated by stirring, the time required being from two to three hours, whereas according to Stead's indirect process the solution is boiled and the sample more rapidly dissolved (in about twenty minutes). Now, in my opinion, the main weak point common to the indirect methods is in the way the dissolving is effected. As is well known, and has been pointed out on several occasions by various authorities,* there is always an evolution of hydrocarbon gases, when steel is dissolved in copper chloride, which escape. In that way I account for the lower results obtained by the indirect processes. It also seems that this evolution of hydrocarbon gases will be more intense the higher the carbon is in the steel, and what is more important, according to my experience in the present research, the same steel has been proved to yield a larger amount of hydrocarbon gases after hardening than was evolved when in an unhardened state. As a proof of this statement I may mention that by testing according to Stead's indirect method a type of Fagersta open-hearth steel in the hardened and unhardened state, the following results were obtained, viz.:—

	Per Cent.
Unhardened steel	0·92 carbon
Hardened at 850° C.	0·78 ,,

It thus appears that the application of either of the indirect methods will necessitate hardened steels being annealed previous to being tested for carbon.

Again, the filtering operation characteristic of the indirect methods not only requires the utmost care and attention so as to avoid a more or less considerable loss of carbon, but also involves a great waste of time. The conclusion to be drawn seems to be that neither of these methods ought to be considered as equal to the direct methods from the point of view of practical convenience, accuracy, or reliability of the results obtained,

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* A. Ledebur, *Prüfung der Zuverlassigheit der gebrauchliohsten Verfahrungsweisen zur Bestimmung des in Eisen enthaltenen Kohlenstoffs, Verhandlungen des Vereins zu Beförderung des Gewerbfleisses*, 1893, vols. vi.-vii. C. G. Saernstroem, *Jernkontorets Annaler*, 1884, pp. 385-402.

owing mainly to the constant source of errors pointed out above, namely, the unavoidable loss of carbon caused by the evolution of hydrocarbon gases taking place during the dissolving process.

As to the direct methods, one will find from the comparative results obtained in the Table (III.) that the most satisfactory results have been obtained by means of the "Stead direct process" and the "Saernstroem method," yielding not only the highest but also the most concordant results.

A rather important point in favour of the "Stead direct process," as compared with the Stockholm method, is the unquestionable saving of time offered by the former, which only requires half-an-hour, whilst the corresponding estimation by means of the other could hardly be achieved in less than one and three-quarters to two hours. It seems to me that these two methods give equally accurate results, and that with the exception mentioned above it would hardly be justifiable to proclaim the precedence of either.

When extending the application of these methods so as to include estimation of carbon in pig iron, the aspect of the matter becomes somewhat different. While being aware that the object of this committee is to test the various methods with regard to their application to steel, it has occurred to me in the course of the present researches, that the value of a method as such also depends upon its having a more or less general application, and that it might thus be of a certain interest to take this opportunity of undertaking some further comparative tests with materials other than steel.

On analysing pig iron according to the Saernstroem method, I have repeatedly stated that the carbon contained therein, the graphite as well as the combined carbon, will be completely oxidised in about two hours. In order to ascertain this, I have used the method of intercepting the gas current every now and then by means of a pinch-cock, and then weighing the absorption tube until there was no further increase in the weight. During the last few years some thirty analyses, in duplicate, of pig iron have been made at the Testing Laboratory of the Royal Technical University in Stockholm by this method, and satisfactory results have always been obtained.

The material selected on this occasion to serve the purpose of testing the value of Mr. Stead's direct process, for estimating carbon in pig iron, consisted of three samples of common pig iron, A, B, and C, together with one sample of ferro-chrome (containing 52·4 per cent. of chromium).

The percentage of carbon according to the Saernstroem method gave the following results, viz.:—

	Per Cent.	Per Cent.
Pig iron, A	Carbon = 2·72	(Graphite = 2·51)
" " B	" = 2·93	(" = 2·76)
" " C	" = 2·86	(" = 2·68)
Ferro-chrome . . .	" = 3·52	...

Before attempting the application of Mr. Stead's direct process to such material, some preliminary experiments were undertaken, by means of which it was ascertained that the sample, when being too strongly heated, caked on the surface and thus prevented the complete combustion of the carbon, and that consequently such excessive heating ought to be avoided; in fact, the carbon obtained by means of this process in the case of sample "A," after four hours of strong heating, was only 1·51 per cent., whereas a subsequent analysis of the same pig iron "A," at a lower temperature, gave the following results, viz.:—

	Per Cent.
After 10 minutes	1·34 carbon
" ½ hour	2·17 "
" 1½ "	2·20 "
" 2½ hours	2·45 "

By using a pulverised sample, there was at last obtained, in the case of this pig iron "A," 2·62 per cent. carbon.

The following table will afford a more convenient survey of the comparative results obtained while applying the two direct methods to this material:—

Description of Material.	Carbon by Saernstroem's Method.	Carbon by Stead's Direct Process.	
		Combustion, 2½ hours.	Combustion, 3 hours.
	Per Cent.	Per Cent.	Per Cent.
Pig iron, A	2·72	2·62	...
" " B	2·93	2·01	...
" " C	2·86	2·57	2·57
Ferro-chrome . . .	3·52	0·67	0·70

On examining the comparative results, it will be seen that Mr. Stead's direct process, however excellent and superior it has proved to be as a method of estimating carbon in steel, could hardly, in its present form, be acknowledged as a suitable method for estimating the carbon in pig iron, whilst, on the other hand, the Saernstroem method has, in fact, proved to be able to give equally satisfactory results in the case of quite different materials, such as pig iron and even certain special alloys of steel which are very difficult to dissolve.

B.—Phosphorus Determinations.

Regarding the phosphorus tests there are only a few remarks to make.

The results of these tests are given in Table III., from which it will be found that the methods used by Baron Jüptner and Mr. Blair have here been omitted. Only the other two—that described by Mr. Stead, and the Eggertz method adopted at the Testing Laboratory of the Royal Technical University in Stockholm, were considered sufficient to serve the purpose of the present researches. The reason for this will be easily understood, for on comparing the detailed descriptions of the Jüptner, Blair, and Stead methods, it will be seen that they are practically the same excepting as regards the mode and manner of ascertaining the weight of the precipitate, a difference so slight as to have no influence on the results obtained.

From the results obtained by the two methods, it is evident that one gives as good results as the other, but it ought to be acknowledged that the comparative rapidity of the process used by Mr. Stead when arsenic is absent constitutes an essential advantage.

In order to ascertain whether arsenic, when present, interferes with the determination of phosphorus in steel, another series of comparative tests were made, in which arsenic acid, equivalent to 0·05 per cent. on the weight, was added to the solution of the steel. The results of these tests were as follows, viz.:—

	H. 971.	M. 76.	H. 737.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Stead's method	0·020	0·024	0·022	0·030
Eggertz' method	0·020	0·022	0·024	0·029

On applying the Stead method, every particular and precaution, as prescribed in the author's memorandum on estimating phosphorus in steel when arsenic is present, were carefully followed, whereas in the Eggertz method the only special precaution strictly observed was that the precipitation of the phospho-molybdate was effected at exactly 40° C.

By means of separate tests it was also found that at higher temperatures than 50° C. there were quite appreciable amounts of arsenic precipitated together with the phosphorus.

METHODS FOR THE DETERMINATION OF CARBON IN STEEL.

By J. E. STEAD.

The system adopted in the laboratory of Messrs. Pattinson and Stead, Middlesbrough, for the determination of carbon in metals and in steel, has been that of direct combustion in oxygen on the one hand, and combustion of the residue after dissolving in potassium cupric chloride on the other. The method adopted for the last twenty-five years has been the latter process, and is in principle identical with that described by Mr. Blair in his work * on "The Chemical Analysis of Iron." There are, however, differences in detail which it is important should be noted.

Instead of the ordinary combustion furnace we have adopted the very excellent gas muffle-furnace supplied by Messrs. Griffin and Co. The body has openings at each side of it so that several tubes can be placed one over the other through the furnace. The muffle itself is removed and the opening is closed

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* Philadelphia. 5th edition, 1902.

by the firebrick doors. Two furnace bodies are placed one above the other. By working in this way with one gas burner it is possible to heat as many as eight tubes and to conduct eight combustions at one time.

The oxygen is distributed to the several tubes, but is first purified by passing through potash and then through strong sulphuric acid.

The tubes themselves are of porcelain, and are 20 inches in length and ¾-inch diameter. They are fitted with india-rubber corks through which pass glass tubes. Plugs of copper oxide are placed in the combustion tubes so as to ensure the oxidation of any CO gas which might be formed during the combustion. After the gases leave the tubes they are passed through U-tubes containing respectively anhydrous copper sulphate, cuprous chloride, chromic acid, and chloride of calcium, and are then passed through tubes, previously weighed, containing soda lime, or through the ordinary potash-bulbs. These absorb the CO_2 produced.

INDIRECT COMBUSTION.

In analysing steel or iron, 2·727 grammes of the material are placed in a No. 4 beaker, and upon this is poured 200 cubic centimetres of a solution of potassium cupric chloride (90 grammes potassium chloride, 40 centimetres strong hydrochloric acid, per litre). The liquid is gently warmed so as to produce circulation, and is finally boiled until the steel is dissolved and no trace of free copper remains. The carbon residue is then filtered through asbestos, and is thoroughly washed with water containing a little hydrochloric acid, and finally with pure distilled water. A little asbestos is pressed upon the surface of the carbon residue, so as to make a sandwich with asbestos on each side and the residue in the centre. The asbestos with residue is removed from the funnel and is pressed into platinum boats 3 inches in length, ⅜ inch in width, and ⅜ inch in depth. The boat with contents is placed in a water-bath to dry, and when completely free from water is ready to place in the combustion tube.

The furnace having been previously lit and the tubes raised to a temperature of about 900° C., the potash absorbing tubes are carefully weighed and a current of oxygen passed through the whole range of the apparatus during a period of ten minutes. Without removing the oxygen in the potash apparatus, they are weighed and again connected up and oxygen passed through for a further ten minutes and are again weighed. The weights should remain constant and show neither any increase or decrease. Should there be an increase in weight there should be an investigation made to discover the cause. Should there be a decrease, it is an indication that the calcium chloride drying tubes at the rear of the potash-bulbs require renewing. If there is no increase or decrease in weight the potash-bulbs are again connected. The india-rubber cork and oxygen connection are removed from the combustion tube and the boat containing the residue is placed therein and is rapidly, with one stroke of a piece of glass rod, pushed into the heated area. The glass rod is withdrawn and the india-rubber cork inserted, an operation which does not occupy more than two seconds. The oxygen gas is turned on and kept flowing until after repeated weighings of the potash absorption bulbs there is no increase in weight. The CO_2 thus obtained is calculated into carbon. The increase in weight of the bulbs in milligrammes indicates the number of hundredths of carbon present in the sample of steel.

At the end of the combustion, by means of a hooked wire, the boat with the residual asbestos is withdrawn from the tube and a second boat containing carbon residue inserted.

The furnace is not allowed to cool between the combustions.

In a single tube it is possible to make at least 10 combustions in six hours, and if there are eight tubes in a furnace it is possible to make about eighty analyses per day.

As a matter of fact, in the furnace employed at Middlesbrough only four tubes are placed in the furnace.

DIRECT COMBUSTION METHOD.

In making a determination of carbon by this process it is absolutely necessary that the turnings should not exceed $\frac{1}{2}$ millimetre in thickness. When the drillings have a greater thickness than this it is advisable to use the cupric potassium chloride process already described. The drillings may be either in the form of shavings or in fine powder; preferably the former. When being burnt, theoretically every particle should be isolated from its fellow so that the oxygen in passing over the material may act on every side of them. In practice this is impossible, but a near approach to it can be effected by mixing the drillings with granulated particles of crushed magnesite brick or with granulated calcined manganese ore. When the drillings consist entirely of spiral pieces there is no need for any admixture whatever, as the oxygen can then act upon all parts without the intervention of any mechanical support. If, however, the particles of steel or metal are in fine powder, it is imperative that this mechanical suspension should be effected.

The boats are made by cutting asbestos sheets into strips about 4 inches long and $\frac{3}{4}$ inch wide, and covering them with china clay on one side, with the aid of a spatula. The strips thus prepared are moulded into boat form by means of the fingers. They are then dried and finally calcined in a muffle-furnace, after which treatment they are ready for use. One boat is required for each combustion.

2·727 grammes of steel with the necessary admixture of granulated magnesite brick or manganese oxide are placed in a boat and the latter is at once put into the heated combustion tube and the metal burnt in oxygen. If the furnace is sufficiently hot, complete combustion should not take more than half-an-hour.

The results obtained by working the two methods above referred to agree most closely, and it has been proved, after three years' constant use of both processes worked side by side, that if the proper precautions are taken the direct combustion process gives most accurate results.

It is necessary at this point to refer to an article written by Mr. Lawrence Duffy which appeared in *Chemical News*, June 19, 1903. In this paper evidence was given as to the value of the direct combustion process, and the method he describes is almost identical with that I have given.

Although Mr. Duffy's proofs of the value of the method are possibly the first to be published, it is nevertheless a fact that for three years previous to the publication of the paper it was in constant use in our own laboratory, and also in one or two of the largest metallurgical steelworks in this country. They are, however, notwithstanding what I have stated, of the very greatest value, as they show that in Sheffield, as in Middlesbrough and in other prominent steelworks, the direct combustion process, if properly carried out in the manner described, is a simple and accurate one of determining the carbon in steel, and one which takes so little time that there should be no objection to using it concurrently with the colour method in iron, steel, and other laboratories.

METHODS FOR THE DETERMINATION OF PHOSPHORUS.

BY J. E. STEAD.

The method employed for the determination of phosphorus is that known by the name of "The Molybdic Acid Process," in which the phospho-molybdate of ammonia after precipitation is weighed and the amount of phosphorus calculated from the weight obtained.

In practice we use two modifications of this method, one in which the steel is dissolved in nitric acid (1·20 sp. gr.) solution decolorised by permanganate of potash, and after the addition of a sufficient quantity of nitrate of ammonia the phosphorus is precipitated with molybdate of ammonia and the precipitate weighed on a tared filter-paper. This system is very useful for steels containing practically no arsenic and silicon.

In the other method precautions are taken to separate any arsenic which might be present.

4·89 grammes of the steel are dissolved in 35 cubic centimetres of nitric acid of 1·42 sp. gr. and 25 cubic centimetres of hydrochloric acid. The solution is evaporated to dryness, taken up with hydrochloric acid, a little water is added, and afterwards pure granulated zinc in quantities sufficient to completely reduce the ferric chloride to ferrous chloride. When the excess of zinc is dissolved, a few drops of ammonium sulphide are added and the solution is violently agitated. If the black sulphide of iron is not completely dissolved, a little more hydrochloric acid must be added until solution is effected. Sulphide of arsenic precipitates at once and coagulates on shaking, and may be filtered off after vigorous agitation or after standing overnight. After filtering, the residue contains the silica and sulphide of arsenic, the filtrate the phosphorus. The filtrate is oxidised with nitric acid after boiling off the free sulphuretted hydrogen, and the bulk of liquid is reduced to 70 cubic centimetres by evaporation. After cooling by placing the beaker in cold water, strong ammonia is added until the solution is just neutral, then 8 cubic centimetres of the same ammonia in excess. Nitric acid is now added until the hydrated oxide of iron has just passed into solution, and a final addition of 5 cubic centimetres nitric acid is added. If the volume of liquid is greater than 100 cubic centimetres it may be evaporated until reduced to that bulk. When boiling, 20 cubic centimetres of a 10 per cent. solution of molybdate of ammonia in water are added, and the beaker with contents well shaken and allowed to stand on the table to allow the phospho-molybdate of ammonia to completely separate. When the supernatant liquid is perfectly bright and the precipitate has settled to the bottom, the solution is filtered through tared filter-papers. These latter are made in the following manner, viz.: Two folded papers after thoroughly drying in a water-bath are placed on opposite pans of an accurately adjusted balance. From the heavier paper portions are clipped off the apex until one filter counterpoises the other. They are then returned to the water-bath for fifteen to twenty minutes. They are then taken out and final and accurate adjustment made. The whole filter is placed inside the other and in this the precipitate is collected.

After washing the precipitate with water containing 1 per cent. nitric acid it is given three washings with distilled water. The filter with contents is then dried at about 110° C.

After drying thoroughly the filters are separated, the counterpoise paper being placed on one pan and the paper with precipitate on the other. Weights are added to the pan with the counterpoise paper until equilibrium is established. The weight thus obtained divided by three gives the exact percentage of phosphorus present in the original metal.

After a considerable number of experiments it has been found in our laboratory that it not infrequently happens that all the phosphorus is not precipitated when the liquid is at a temperature of 40° C. and under.

We find, furthermore, that on precipitating at a higher temperature than 40° C. arsenic, if present, is liable to come down with the phosphorus precipitate. The amount varies considerably, and the exact law which determines the quantity so precipitated has not been fully ascertained. For these reasons we consider it advisable invariably to separate the arsenic in the first instance, and then to precipitate at a sufficiently high temperature to ensure complete precipitation of the phosphorus.

TABLE IV.—RESULTS OBTAINED BY J. E. STEAD.

Carbon Determinations.

Method Employed.	H. 971.	M. 76.	H. 739.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Direct combustion	1·44	1·035	0·42	0·10
Variations	0·03	0·02	0·02	0·01
Averages	1·44	1·035	0·42	0·10
Solution in cupric potassium chloride, and combustion of residue—				
Variations	0·03	0·04	0·02	0·01
Averages	1·40	1·02	0·42	0·096
Baron H. von Jüptner's method—				
Averages	1·375	1·015	0·436	0·088
Saernstroem's method—				
Variations	...	...	...	...
Averages	1·404	1·033	0·425	0·093
Phosphorus Determinations.				
Method used in Mr. Stead's laboratory—				
Variations	0·002	0·002	0·002	0·002
Averages	0·0230	0·0245	0·0245	0·0295

As there was not sufficient of the standard drillings to make further investigations, trials were made with Eggertz's method on drillings from other samples of steel similar to those experimented upon by the committee.

	Percentage of Phosphorus.			
	No. 1.	No. 2.	No. 3.	No. 4.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Eggertz's method	0·021	0·022	0·024	0·022
Stead's method	0·022	0·022	0·025	0·023

REPORT BY J. E. STEAD.

The results obtained in my laboratory lead to the following conclusions on the relative value of the several methods of analysis:—

CARBON DETERMINATIONS.

Method of Baron H. von Jüptner.—This indirect wet combustion process yielded lower carbon results than any of the other methods.

Method of Saernstroem.—This is a direct wet combustion process and yielded results closely concordant with the percentages of carbon obtained by the dry combustion method.

Theoretically there is no objection to this method. The precaution taken to pass the gases evolved mixed with air through a red-hot tube effectually prevents the escape of any hydrocarbons.

The Direct Combustion Method.—The direct combustion of steel in a current of oxygen gas has long been in use, but until the last few years it was considered necessary to mix the steel drillings with oxide of copper, chromate of lead, oxide of lead, or other oxidising substances previous to burning it in the combustion tube. Since oxygen, perfectly free from impurities, has been commercially obtainable, experiment has shown that it is not usually necessary to make any such admixture, and that if the temperature of the furnace is sufficiently high, and the drillings of steel not too fine or too coarse, combustion may be effected rapidly and completely, the whole of the carbon being obtained as carbonic anhydride.

My attention was drawn to the value of this method by one of my old pupils who had used it with success in a large steelworks in England in 1890.

In my opinion this method holds the premier position.

The Indirect Combustion Method.—This method has long been in use, and is recognised as the standard method in England and America.

The results obtained by its use in this investigation were rather lower than those obtained by the direct methods, but in general practice such variations are unusual.

For more than three years it has been the practice in our laboratory, whenever possible, to test samples of steel received for analysis by both the indirect and direct dry combustion processes. The results have, almost without exception, closely agreed.

The copper chloride method described so fully by Mr. Blair is practically the same as that used in Middlesbrough, but the system for mechanically agitating the cold cupric liquor adopted by Mr. Blair is an improvement on the method I have used, and one which should be generally adopted.

It will be noted that the results obtained by Mr. Blair closely agree with those obtained in Middlesbrough.

Grey pig metals in the form of drillings are invariably tested by the cupric potassium chloride method. The direct process is unsuitable for the determination of carbon in such metals.

DETERMINATION OF PHOSPHORUS.

All the methods employed in this research are modified varieties of the molybdic acid method.

Baron H. von Jüptner's Method.—This method is practically identical with the Eggertz method, the only difference being in the mode of weighing the precipitate.

No trials were made by the special method of weighing adopted by Baron H. von Jüptner.

Eggertz's Method.—The Eggertz method of determining phosphorus appears to give good results, but in past experience it has been found, more particularly in the case of pig irons, that occasionally the phosphorus is not completely precipitated by heating to 40° C., and that therefore it is liable to give lower results than the truth. There is also the objection that the solution containing the phosphorus has to stand for many hours at a temperature of 40° C. to allow the precipitate to separate.

The pre-separation of Arsenic Method.—When arsenic is absent the phosphorus may be precipitated at between 80° and 100° C., and it all falls out of solution in less than one hour.

Although more laborious, it has been found that it takes less time to obtain a result if arsenic is first separated than when following the method of Eggertz.

Many years ago it used to be a common practice to filter the phospho-molybdate upon smooth English filter-papers, to brush the precipitate off when quite dry, and weigh it separately; but such a procedure invariably gave low results, because it was impossible to remove the whole of the precipitate from the pores of the paper.

The method adopted by Mr. Blair and the American chemists of dissolving the precipitate from the paper in ammonia and reducing the solution afterwards, and determining the molybdenum volumetrically, and the method by Messrs. Brearley and Ibbotson of determining the molybdenum in the precipitate by precipitation with a salt of lead, are very excellent and free from objection, but when one has some twenty or thirty phosphorus determinations to make per day, the extra manipulation required is very considerable, as compared with weighing the precipitate directly upon properly tared filters.

It seems to be incontrovertible that if the original precipitate is capable of being accurately weighed there is no need whatever to make the process more complicated.

The method of weighing on counterpoised filters has been found to be accurate. If there is any objection to weighing the filter-papers the precipitate can be weighed in Gooch crucibles, or in glass filter-tubes suitably arranged with asbestos plugs at their bases.

Review of the Work Done.

The following table gives the averages of the results obtained by working with the methods approved by each analyst, viz.:—

TABLE V.—AVERAGES BY METHODS APPROVED BY EACH ANALYST.

Carbon Determinations.

	H. 971.	M. 76.	H. 739.	L. 422.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Dillner	1·46 1·45	1·02 1·01	0·45 0·44	0·10 0·10
Jüptner	*a* 1·57 *b* 1·52 *c* 1·439 *d* 1·450	1·105 1·071 1·046 1·068	0·459 0·439 0·424 0·459	0·141 0·0936 0·140 0·142
Blair	1·415 1·412	1·040 1·038	0·434 0·432	0·098 0·097
Stead	1·44 1·40	1·035 1·020	0·420 0·420	0·10 0·096
Phosphorus Determinations.				
Dillner	0·0225	0·0225	0·0230	0·030
Jüptner	0·0305	0·0320	0·0275	0·027
Blair	0·0190	0·0180	0·0220	0·026
Stead	0·0230	0·0245	0·0245	0·0295

Baron H. von Jüptner has not tested the samples by the method he handed to the committee, and does not give any opinion as to what method he considers best.

Neither Baron H. von Jüptner nor Mr. Blair has employed the direct dry combustion process.

On comparing the above results it will be seen that the greater part of the determinations agree closely, but there are exceptions to this rule.

With regard to the methods for the determination of carbon, Mr. Dillner and Mr. Stead both agree in strongly recommending the two direct combustion processes. It will, however, be noticed that excepting in high carbon steel the results obtained by the cupric chloride indirect method agree very closely with those obtained by the direct processes.

Theoretically the wet and dry combustion processes should give the most trustworthy results.

With regard to the phosphorus determinations, the results are again somewhat variable.

Mr. Blair's results are generally lower than those obtained by the other analysts. The results of Messrs. Dillner and Stead agree throughout very closely, whereas those obtained by Baron H. von Jüptner are, with one exception, higher than the others. Theoretically there is no reason why they should not agree. They were all obtained by the molybdate process, Mr. Blair having determined the molybdenum precipitated volumetrically, whilst Baron H. von Jüptner adopted a method which slightly differs from that of Messrs. Dillner and Stead in the system of weighing.

The committee are continuing their investigations, and are endeavouring to ascertain whether, or not, hydrocarbon gases do escape when steel is dissolved in cupric potassium chloride, and the reasons for the discrepancies shown above, the results of which will be presented on some future occasion.

CORRESPONDENCE.

Mr. R. HAMILTON (Glengarnock) wrote to say that it was known for many years, that unless certain precautions were taken in dissolving the sample, there was a liability to obtain a solution from which the ammonium-molybdate solution would not precipitate the whole of the phosphorus. In 1877 Blair and Finkiner independently attributed this interference to the presence of carbonaceous matter in the solution, derived from the action of acids on the combined carbon of the metal, and they directed that the solution should be prepared in such a manner as to destroy these carbonaceous compounds. This was practically effected by evaporating the acid solution to dryness and roasting the residue. Adolf Tamm, in 1884, accentuated the same view. There are methods founded on the above-mentioned observations which leave nothing to be desired in point of accuracy, but the evaporation to dryness with subsequent roasting and re-solution consumes much time, besides the minor inconvenience caused by large amounts of acid fumes. In 1888 P. W. Shimer suggested that the incomplete precipitation of phosphorus was due to incomplete oxidation of the phosphorus, and proposed to render all the phosphorus precipitable by oxidising the solution with potassium permanganate, &c. Experiments were made to test the accuracy of this view (details will be found in the *Journal of the Society of Chemical Industry*, vol. x. p. 904), and the results obtained seem to prove that it is the correct one.

It was first proved that carbonaceous matter in solution did not prevent the precipitation of properly oxidised phosphorus as ammonio-phospho-molybdate. This was done by using a pig iron low in phosphorus but high in combined carbon, and adding known quantities of a solution of phosphoric acid to it; this addition was made both before and after the solution of the iron in nitric acid, and in all cases the whole amount of phosphoric acid was obtained, though the solutions were not evaporated to dryness, in some cases, indeed, only to half bulk. The next step was to find if the phosphorus in iron could be rendered completely precipitable by oxidation while in solution.

For this purpose there was used a sample of white pig iron containing 2·54 per cent. of combined carbon and 1·36 per cent. of phosphorus. By dissolving as usual, evaporating to half bulk and precipitating, without any attempt at oxidation, two-thirds of the phosphorus was obtained: the filtrate from the yellow precipitate was worked with to induce further precipitation, but no more came down. In a supplementary experiment the remaining one-third of the phosphorus was obtained in the filtrate from the yellow precipitate by oxidising the said filtrate. Several methods of oxidation were tried, details of which will be found in the original paper; the method found to give the best results was to oxidise with permanganate and remove the resulting precipitate with hydrogen peroxide. By this means the whole of the phosphorus was obtained, and that in a very short time. The iron was dissolved in nitric acid of 1·135 or 1·2 specific gravity, oxidised twice with permanganate (removing the precipitate with hydrogen peroxide) neutralised with ammonia between the two oxidations, the flask stoppered and shaken vigorously for five minutes, cooled, and filtered straight off. The phosphorus was weighed as magnesium pyrophosphate, and the precipitate proved free from silica. The whole of the phosphorus was also obtained by dissolving the iron in hydrochloric acid with addition of bromine.

The following is the summary of the original paper: "I think it may be fairly assumed that the two sets of experiments described prove to satisfaction—(1) that the carbonaceous matter in a solution of iron does not prevent the complete precipitation of properly oxidised phosphorus as ammonio-phosphomolybdate; (2) that the reason of the incomplete precipitation of phosphorus from a nitric acid solution of iron, which has not been evaporated to dryness and roasted, is that the phosphorus has not all been oxidised; (3) that in such solutions, all the phosphorus can be rendered completely precipitable, in the wet way, by means of certain oxidising agents."

Though it is thirteen years since the paper was read, and though the method described presents many advantages, the writer finds that it is not generally adopted. He has made these notes with the double object of giving credit to those who made the discovery of the important influence of permanganate, and of drawing attention to the fact that their observations have been fully confirmed.

Mr. E. H. SANITER (Rotherham) wrote referring to Mr. Gunnar Dillner's remarks on the direct combustion of ferro-chrome for carbon, and pointing out that it might be interesting to state that by mixing the ground ferro-chrome with oxide of copper containing 25 per cent. of litharge (PbO) the whole of the carbon was burnt off in thirty minutes.

Mr. STEAD, in reply to the correspondence, said he, as one of the committee, welcomed the remarks of Mr. Hamilton, as they show how important it is that the phosphorus should be fully oxidised to P_2O_5. He (Mr. Stead) had not found it necessary to use permanganate when strong hydrochloric acid was employed for dissolving steel, but if weak nitric acid were used, the phosphorus was not fully oxidised, and it then became necessary to use it. In regard to Mr. Saniter's remarks, he quite agreed that the method he described would give correct results.

The following paper was the first read at the meeting on October 26, 1904:—

THE APPLICATION OF DRY-AIR BLAST TO THE MANUFACTURE OF IRON.

BY JAMES GAYLEY, NEW YORK.

THE atmosphere, which plays such an important part in the manufacture of iron and steel, is the most variable element involved in its several processes; and particularly is this true of the blast-furnace process, which consumes air in large quantities. At no time since the blast-furnace became an important and widely used apparatus—even when it was operated in the most crude manner—have the variations in composition of the raw materials used been as frequent and as great as the variations in humidity of the atmosphere. Important improvements have been made in the blast-furnace and its accessories, such as the hot-blast stoves, the increase in size and change in the shape of the furnace, more efficient blowing-engines, the increased protection given to the bosh walls, and the careful preparation of the raw material, all of which have exerted a pronounced influence on the furnace operations from a metallurgical standpoint. But during the past eight years little advance has been made in this direction; the fuel consumption has not diminished, nor has there been any material increase in production. Within that period, however, there has been witnessed the greatest development in appliances for the economical handling of material. So complete has been the work in this direction, that except in isolated cases, in this country at least, a further extension does not hold out much promise of a satisfactory return on the investment required. It seemed that, with the exception of the gas-engine, we had about reached the limit, for like a strong wall, the atmosphere, with its humidity, as variable to-day as when first blown into a primitive blast-furnace, appeared to stand as a barrier to further progress. In furnaces using ore from the Lake Superior district, the raw material amounting to about 7200 lbs. per ton of iron, varies in composition within 10 per cent., and is as uniform as human skill can make it; but the atmosphere, of which 11,700 lbs.

are consumed per ton of iron, varies in its content of moisture from 20 to 100 per cent., from day to day and often in the same day, thus rendering the process, even with the best appliances, an uncertain one, because dependent on the caprice of the atmosphere.

The desiccation of the air used in blast-furnaces in such a way as to reduce its moisture to a small quantity, and to keep it uniform, must of necessity contribute in a very marked degree toward the attainment of uniformity in the furnace operations. The advantages from desiccation can be appreciated only after due consideration is given to the volume of air that is consumed per minute and the large amount of moisture which it contains. Managers of blast-furnaces are familiar with the chilling effects produced in the hearth by a tuyere that is leaking, which immediately results in a deterioration in the grade of the iron; yet the quantity of water ordinarily entering the furnace under these conditions is not greatly in excess of the quantity carried in, like a steady stream, by the atmosphere during a period of the average humid conditions prevailing in the summer season in this country.

It has been deemed preferable in this communication to express the quantity of moisture, contained in the atmosphere as aqueous vapour, in grains of water per cubic foot of air, inasmuch as the quantity of air blown into blast-furnaces is expressed in cubic feet. With air containing 1 grain of water per cubic foot, there is passed into the furnace, for each 1000 cubic feet used per minute, practically 1 gallon of water per hour. A furnace of average size in the Pittsburg district consumes about 40,000 cubic feet of air per minute, which would pass into the furnace 40 gallons of water per hour for each grain of moisture contained in a cubic foot of air. The quantity of moisture in the air, taken from daily readings by the observer of the United States Weather Bureau at Pittsburg, is set forth in Table I.

Table I., like all records made by the U. S. Weather Bureau, is from observations taken on the top of a high building, and does not correctly indicate the condition of the atmosphere at the furnaces where the air is used. In fact, at one of the steelworks in Pittsburg, observations made simultaneously at three separate stations showed a perceptible variation in

TABLE I.—*Moisture in Air at Pittsburg. U. S. Weather Bureau.*

	Average Temperature.	Weight of Water per Cubic Foot of Air.	Quantity of Water entering per Hour into a Furnace using 40,000 Cubic Feet of Air per Minute.
	Degrees Fahrenheit.	Grains.	Gallons.
January	37·0	2·18	87·2
February	31·7	1·83	73·2
March	47·0	3·40	136·0
April	51·0	3·00	120·0
May	61·6	4·80	192·0
June	71·6	5·94	237·6
July	76·2	5·60	224·0
August	73·6	5·16	206·4
September	70·4	5·68	227·2
October	56·4	4·00	160·0
November	40·4	2·35	94·0
December	36·6	2·25	90·0

moisture. For the purpose of comparison with observations of the U. S. Weather Bureau, there is shown in Table II. the average monthly content of moisture in the air at the furnaces, the observations being made at 9 A.M.

TABLE II.—*Moisture in Air at Steelworks in Pittsburg.*

	Weight of Water per Cubic Foot of Air. Grains.
January	2·8
February	2·7
March	3·1
April	3·3
May	4·7
June	7·3
July	7·0
August	7·1
September	5·4
October..	3·2
November	3·3
December	3·0

The variations in moisture from month to month set forth clearly the conditions, as to atmosphere, with which blast-furnaces in this country have had to contend. If these conditions were uniform throughout the whole month, it would not be a difficult problem to deal with; but unfortunately they are not uniform, and it is instructive to note the changes which occur from day to day in the same month. In Table III. is shown a record worked out from data furnished by the U. S. Weather Bureau at Pittsburg. These observations represent a different period from that shown in Table I.; they were taken at 8 A.M. and 8 P.M., and show the grains of water per cubic foot of air at the time observed, for the months of January and July.

TABLE III.—*Moisture in Air at* 8 *a.m. and* 8 *p.m.*

Day of Month.	January.		July.	
	Quantity of Water.		Quantity of Water.	
	8 A.M.	8 P.M.	8 A.M.	8 P.M.
	Grains.	Grains.	Grains.	Grains.
1	1·96	3·06	7·24	7·48
2	2·55	3·66	8·23	7·98
3	2·46	3·80	8·50	7·48
4	2·07	2·27	8·50	7·48
5	1·81	1·12	8·46	7·72
6	0·99	1·12	6·50	8·24
7	1·16	1·67	8·78	7·47
8	1·49	1·88	7·98	7·24
9	1·96	2·19	6·78	5·94
10	1·81	1·88	7·48	6·35
11	1·74	1·55	7·98	7·48
12	1·55	1·07	6·73	6·35
13	0·99	1·55	5·94	4·84
14	1·61	1·81	5·55	5·74
15	1·67	1·96	5·74	5·19
16	2·04	2·27	6·35	6·35
17	2·45	3·29	7·72	7·98
18	1·81	1·32	7·24	7·24
19	1·12	1·16	8·24	7·48
20	1·43	2·11	7·48	7·24
21	2·11	1·88	7·72	7·38
22	1·88	1·88	6·78	5·74
23	0·91	1·17	7·43	6·35
24	0·99	2·11	6·56	6·11
25	0·69	1·83	6·05	7·74
26	0·61	0·99	7·72	7·32
27	0·56	0·88	7·98	7·48
28	0·72	0·70	6·56	5·74
29	0·76	0.80	6·14	5·01
30	0·95	1·12	5·74	6·35
31	0·70	1·41	6·56	5·19

It will be observed from the data in Table III., that while the moisture in the atmosphere in the month of January is much less than in July, yet the percentage of variation is greater. In order to illustrate more precisely the exact conditions, with respect to the atmosphere, under which blast-furnaces must be operated, there is shown in Tables IV. and V. a record of observations taken each hour in the day. In order not to make the data too burdensome the months of April and October have been selected, as they represent months between the warm and cold seasons, and will also serve for comparison with January and July, as shown in Table III.

It should be stated with reference to the Tables IV. and V., that observations were taken with a stationary instrument, which shows results somewhat higher, and not as accurate, as those taken with a whirled psychrometer. Nevertheless, they were taken with the same instrument and are relatively correct. By simply multiplying the grains of moisture by 40—which represents the number of gallons of water entering a modern furnace per hour, for a content of 1 grain of moisture in a cubic foot of air—a clear idea can be had of the gallons of water entering the furnace per hour, for the various conditions of humidity. The changes are great not only from day to day, but from hour to hour in the same day, and often they are very abrupt. These records were made at a furnace-plant, situated on the bank of a river, where the conditions exist for an increased humidity as compared with higher ground; and to what extent the abrupt changes may have been caused by the presence of steam in the atmosphere—absorbed from spraying of the hot pig-beds, the blow-off from boilers and exhaust from engines, or from a rainstorm, when the humidity decreases suddenly—it is impossible to say. How frequently has it happened in the experience of every furnace manager, that the furnace has gradually or suddenly lost its hearth-temperature and produced a grade of iron either undesirable or unmarketable, without any visible cause. Tuyeres are examined for leaks, the raw material in the stock-yard is carefully inspected, and usually the coke is condemned. A more intimate acquaintance with the atmosphere would have provided a correct and ready reason, for the variations therein are not only many times greater than in the raw material, but a greater weight of it is used per ton of iron.

It is true that the atmosphere has been recognised by numerous metallurgists as the cause of many serious irregularities in blast-furnace operations, but it is doubtful whether its

TABLE IV.—*Hourly Record of Moisture in Air.*

Grains of Moisture per Cubic Foot of Air.

April.	A.M.							P.M.												A.M.				
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	2·77	3·30	3·71	3·71	3·09	3·46	3·46	3·46	3·46	3·46	3·46	4·11	3·71	3·71	3·71	3·30	3·71	3·71	3·71	3·30	3·71	3·71	3·71	3·09
2	3·71	3·71	3·30	3·30	3·71	3·71	3·46	3·46	3·46	3·81	3·46	3·81	3·09	3·81	3·30	3·77	2·77	3·71	3·71	3·71	3·71	3·71	3·68	3·30
3	3·09	3·09	3·09	3·09	3·46	3.46	3·46	3·09	3·09	3·46	3·09	3·30	3·30	3·02	3·02	3·30	3·30	3·30	3·30	3·30	3·30	3·30	3·30	3·30
4	3·71	3·71	3·71	3·71	3·71	4·11	4·11	4·67	4·67	3·81	3·81	4·11	3·30	4·01	3·30	3·71	4·01	3·71	3·71	3·30	3·38	3·30	3·30	4·01
5	3·68	3·68	4·01	3·30	4·01	3·89	3·71	4·11	4·11	3·46	4·11	4·11	4·11	3·46	3·09	3·09	3·09	2·47	2·77	2·77	2·77	2·77	2·77	2·77
6	2·47	3·09	3·09	3·09	3·71	3·71	3·71	3·71	3·46	3·46	3·71	3·71	3·71	3·71	3·71	3·71	3·09	3·30	3·30	3·30	2·77	2·77	2·77	2·47
7	2·77	3·30	3·30	2·77	4·01	3·30	3·71	3·81	4·11	4·33	4·67	4·67	4·11	4·01	3·30	3·30	3·71	3·71	3·30	3·30	3·30	3·30	3·30	3·30
8	3·02	3·30	4·01	3·30	3·71	3·71	3·71	4·11	4·11	4·40	4·40	4·40	3·71	3·71	4·01	4·01	3·30	3·30	3·30	3·30	3·30	3·02	3·02	3·30
9	3·68	3·68	3·71	4·11	4·11	4·11	4·28	4·67	4·01	4·01	4·31	4·31	3·68	3·68	3·68	4·01	3·68	3·68	3·30	3·39	3·39	3·02	3·39	3·02
10	3·68	3·68	3·98	3·68	3·68	4·01	3·71	3·71	4·67	4·17	5·11	5·46	5·11	5·35	5·11	5·14	5·35	5·20	4·75	4·40	4·75	4·40	4·75	4·75
11	4·75	4·31	4·40	5·01	4·33	5·28	4·56	4·56	5·22	5·22	5·22	5·22	4·24	4·96	3·81	3·81	3·46	3·46	3·81	3·81	3·46	3·46	3·46	3·46
12	3·46	3·46	3·30	3·46	3·98	3·30	3·84	3·68	3·47	3·20	3·52	3·52	3·17	3·11	2·74	3·98	3·46	3·71	3·71	3·09	3·09	3·30	3·30	3·30
13	3·02	3·68	3·71	4·01	4·96	4·71	5·22	4·85	4·59	4·85	4·56	4·56	4·56	4·96	4·96	4·67	4·81	5·01	5·01	4·75	4·75	4·31	4·31	4·31
14	3·68	3·68	3·68	3·68	4·31	4·01	4·01	4·01	4·01	4·31	4·31	4·40	4·31	4·31	4·31	4·31	4·31	3·98	4·31	3·68	3·98	4·31	3·98	3·98
15	4·01	4·01	3·71	4·40	4·41	4·75	4·33	4·96	4·56	4·24	4·24	4·24	4·33	3·81	4·11	3·81	3·46	3·30	3·30	3·30	3·30	3·68	3·62	3·62
16	3·68	3·68	4·01	3·81	3·81	4·67	3·52	4·96	4·96	4·96	4·96	4·96	4·96	5·01	4·40	4·40	4·11	4·75	4·46	4·67	5·01	5·01	5·01	5·01
17	5·01	4·67	5·60	5·26	5·28	5·97	6·27	6·27	6·27	6·27	5·83	6·27	6·25	5·60	5·60	5·60	5·35	5·35	5·77	4·40	4·75	4·75	4·75	4·52
18	4·75	4·75	5·35	5·35	5·35	5·32	5·60	6·08	6·43	6·43	6·62	5·84	5·84	5·84	5·77	5·77	5·11	5·11	5·77	5·77	5·77	5·35	5·77	5·77
19	5·77	5·35	5·77	5·77	6·32	5·77	6·32	6·32	6·32	6·32	6·32	5·84	6·72	5·77	4·75	4·75	4·75	4·01	4·01	4·31	3·30	3·30	3·30	4·01
20	4·01	3·30	3·30	3·30	3·30	3·30	3·30	3·71	4·40	4·40	4·40	4·40	3·71	3·30	3·30	3·30	3·30	3·30	3·09	3·30	3·30	3·30	3·30	3·30
21	4·01	4·40	4·40	3·71	3·71	4·40	4·11	4·11	4·11	4·67	5·01	5·01	5·35	4·01	4·01	4·01	5·11	4·75	4·31	4·01	4·01	4·31	5·11	4·31
22	3·30	4·01	3·46	3·71	4·11	4·11	4·33	4·56	4·98	5·22	5·59	5·10	4·04	4·24	4·56	4·24	5·22	5·22	5·22	5·59	5·59	5·28	5·01	4·40
23	5·35	5·01	5·01	5·60	5·28	5·28	5·84	5·35	6·18	6·18	6·18	6·18	6·18	6·39	6·39	6·18	6·18	6·18	5·77	6·18	6·18	6·18	5·11	5·11
24	5·46	5·11	5·11	5·11	5·11	5·11	5·11	5·11	4·75	5·11	4·75	5·77	4·75	5·11	5·11	5·46	5·77	5·77	5·35	4·75	4·75	5·11	5·11	4·75
25	4·31	4·41	4·75	4·75	4·40	4·40	4·40	5·01	5·01	5·01	5·01	5·01	4·75	4·75	4·40	4·40	3·71	3·75	4·05	4·00	4·01	4·01	4·01	4·01
26	4·01	4·40	4·11	4·11	4·61	4·67	4·67	4·67	4·67	4·67	4·33	4·33	4·33	4·33	3·71	4·01	4·31	4·01	3·68	4·01	3·30	3·68	3·68	3·68
27	4·31	4·01	4·40	4·11	4·67	4·67	4·96	4·33	4·33	5·28	4·33	4·96	4·67	3·71	4·01	4·40	4·01	4·01	4·01	4·01	3·68	3·68	3·68	3·68
28	3·30	4·01	3·46	3·81	4·11	4·11	4·67	4·67	4·67	5·28	5·28	4·33	5·01	4·40	4·11	4·40	4·40	4·40	3·71	4·31	4·01	4·01	3·71	4·40
29	4·01	4·01	4·40	4·40	4·40	4·11	4·11	3·81	4·40	4·40	4·11	4·40	4·40	4·01	4·31	4·75	4·75	4·07	4·01	4·01	4·01	4·01	4·31	4·01
30	4·01	3·68	4·31	3·81	4·67	4·33	5·60	5·28	5·97	6·43	5·28	5·28	5·84	5·01	5·35	5·77	4·75	4·75	4·75	5·11	4·75	4·75	4·75	4·75

TABLE V.—*Hourly Record of Moisture in Air (Continued).*

Grains of Moisture per Cubic Foot of Air.

October.	A.M.							P.M.												A.M.				
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	5·46	6·18	7·08	6·62	6·27	6·27	6·64	6·39	6·39	7·73	7·73	7·65	8·15	7·65	7·16	7·08	6·32	7·08	6·32	6·72	6·72	7·20	6·18	6·18
2	7·20	7·92	8·86	9·38	9·02	10·15	10·15	10·15	10·10	10·15	10·15	9·38	10·02	10·02	8·86	8·86	8·86	7·92	7·92	8·86	8·40	8·40	8·40	7·20
3	7·92	7·92	9·38	9·02	9·57	9·57	9·13	9·78	9·78	9·14	10·89	10·15	8·54	8·54	8·54	8·86	7·92	7·92	7·64	8·86	8·54	9·51	7·92	9·05
4	9·05	7·92	8·54	9·02	10·15	10·15	10·15	9·02	10·02	10·02	10·27	10·02	9·02	9·38	9·38	9·02	8·86	8·36	9·05	9·84	9·51	9·84	8·40	9·84
5	8·40	9·51	9·51	8·40	9·51	9·51	9·51	8·86	8·86	8·54	8·54	9·51	7·64	7·64	7·64	7·92	8·40	6·72	7·92	6·72	5·77	5·77	5·77	5·35
6	5·35	5·35	5·35	5·01	5·60	5·28	4·96	5·59	5·22	5·22	5·59	5·28	5·01	5·35	5·11	5·11	5·11	5·11	5·11	5·46	5·99	5·11	5·77	5·11
7	6·18	6·18	5·77	5·35	6·32	6·32	7·64	7·92	7·20	8·40	7·92	7·92	7·52	7·20	7·20	7·20	7·20	7·20	7·20	7·20	7·52	7·52	7·52	6·18
8	7·20	7·20	7·20	6·72	6·72	5·60	5·28	6·43	6·43	5·81	6·32	6·72	6·72	6·72	5·77	5·77	5·77	5·77	6·18	5·77	6·18	5·11	6·18	5·11
9	5·46	5·46	6·18	5·35	4·67	4·56	4·85	5·22	4·85	5·22	4·56	5·77	4·40	5·11	5·11	5·11	4·31	4·31	4·40	5·11	5·11	4·31	4·66	4·66
10	4·66	5·11	4·75	4·75	5·77	6·62	7·47	7·47	8·15	7·25	6·71	6·47	7·08	7·08	7·08	7·47	7·25	6·71	6·71	6·43	6·43	5·60	5·84	...
11	6·32	6·43	6·71	6·27	5·83	6·39	6·71	5·97	5·35	4·75	4·75	4·75	6·72	5·77	5·77	5·77	5·77	6·18	6·18	4·66	4·31	5·11	5·11	4·31
12	4·31	3·75	4·01	3·81	4·33	3·98	3·71	3·71	3·71	3·98	3·98	3·52	3·52	3·82	3·81	4·01	4·01	4·01	4·31	4·31	4·31	4·31	4·31	4·31
13	4·31	4·31	4·01	5·01	5·28	5·28	4·85	4·85	4·47	4·24	4·24	4·56	4·67	4·67	4·67	4·75	5·35	4·75	5·11	4·75	4·75	4·40	3·81	3·46
14	3·11	3·11	3·46	3·11	3·11	3·11	3·11	2·75	3·46	3·71	3·71	3·71	3·71	3·71	3·71	4·01	4·01	3·71	4·11	4·11	4·11	4·11	3·46	3·46
15	3·81	3·46	3·46	3·11	3·11	3·81	3·81	3·52	3·98	3·52	3·52	3·11	3·81	3·11	4·01	4·01	3·30	3·30	3·68	3·68	3·68	3·68	3·68	3·68
16	3·68	3·68	3·68	4·01	4·11	4·33	3·33	4·33	3·98	3·98	5·01	3·71	4·40	4·01	4·01	4·01	4·01	4·01	4·01	4·01	3·71	3·71	3·71	3·71
17	3·71	3·71	4·40	3·81	3·30	3·84	4·01	4·01	4·01	4·47	4·47	4·47	3·52	3·84	3·84	3·30	4·24	3·30	3·71	4·74	6·67	4·67	4·33	3·81
18	4·40	4·75	4·75	4·75	4·75	4·75	4·75	5·11	4·75	4·75	4·75	4·11	4·11	4·40	4·11	4·40	4·11	4·40	3·71	3·71	3·71	3·71	4·01	3·71
19	3·71	3·68	4·01	4·11	3·98	3·71	3·30	2·95	2·95	3·84	3·84	3·98	3·98	3·81	4·11	3·71	3·46	3·71	4·01	4·01	4·01	3·68	4·01	4·01
20	3·68	3·68	4·01	4·01	4·33	4·56	3·84	4·85	3·82	4·01	4·24	4·24	4·67	4·11	4·11	4·40	4·40	4·40	4.11	4·11	5·01	4·40	4·75	4·75
21	5·77	5·35	5·77	5·77	6·18	5·77	5·77	5·77	5·77	5·35	6·32	5·01	5·35	5·35	5·77	6·72	5·35	5·35	5·77	5·77	4·40	4·40	4·40	3·46
22	3·46	3·46	3·46	3·46	3·46	3·11	3·46	3·46	3·46	3·46	3·46	3·52	3·81	3·81	3·52	3·11	3·11	3·81	3·81	3·81	3·81	3·81	3·81	3·81
23	3·52	3·52	3·17	3·52	2·75	3·52	3·17	3·17	3·52	3·17	3·52	3·11	3·52	3·52	3·11	3·11	3·46	3·46	3·46	3·09	3·71	3·09	3·30	3·30
24	3·30	3·30	3·71	3·46	4·33	3·98	4·96	4·56	4·24	4·24	4·56	4·67	3·81	4·11	4·11	4·11	4·40	3·71	3·71	3·71	3·71	4·01	4·01	3·71
25	4·01	3·30	3·71	4·11	4·33	4·24	4·85	4·85	4·01	4·47	3·84	3·98	4·33	4·11	3·46	3·71	3·71	4·01	4·40	4·40	4·11	4·11	4·11	4·11
26	4·16	3·71	3·46	3·46	2·74	2·75	2·75	2·75	3·11	3·46	3·46	3·09	3·11	3·46	3·11	2·74	2·74	2·74	2·52	2·75	2·23	2·52	2·74	2·52
27	2·52	2·23	2·52	2·23	2·23	2·23	2·23	2·75	2·75	2·45	2·45	2·52	2·74	2·74	2·74	3·09	3·09	3·09	2·47	3·09	3·09	3·09	2·47	3·09
28	3·30	3·30	2·74	3·46	2·75	2·75	2·94	2·94	3·30	3·30	2·94	2·75	2·74	3·11	3·46	2·74	3·09	3·46	2·74	3·09	3·46	3·09	3·09	3·30
29	2·74	2·74	2·74	3·09	2·75	3·52	3·71	2·95	3·30	3·30	2·58	3·81	3·11	3·11	3·46	3·11	3·46	2·75	3·11	3·11	3·09	3·09	3·09	3·09
30	3·30	3·46	3·30	3·46	4·01	3·71	3·46	3·46	3·46	3·11	2·75	3·17	2·75	3·11	3·46	3·46	3·11	3·11	3·11	3·11	3·46	3·46	2·74	3·71
31	3·71	3·71	3·71	3·71	3·71	3·71	3·71	3·71	3·46	3·46	3·46	2·75	3·46	3·46	3·09	3·09	3·09	3·09	3·09	3·30	3·39	2·77	3·09	3·30

influence has been adequately recognised. Many writers on metallurgical subjects have considered the moisture in the atmosphere, and calculated—and invariably underestimated—the absorption of heat necessary for its dissipation; and have dismissed the subject with the conclusion that to extract the moisture the game was not worth the candle, or in a spirit of resignation accepted it—like storm and sunshine—as a condition beyond our control. This conclusion has no doubt been reached by a consideration alone of the quantity of fuel necessary to dissipate the moisture in the furnace hearth, based on observations of the humidity of the atmosphere taken outside the blowing engine-room; and this quantity, while important, does not indicate a great saving in fuel. Of much greater importance is the variation in moisture from time to time and the margin of heat carried in the furnace to compensate for these variations, which margin is invariably large; and every furnace manager is aware of its existence from the way in which he is required to manipulate the hot-blast temperatures, and from the silicon in the metal, which is the thermometer of the hearth.

It has often been a matter of surprise that a greater saving of fuel per ton of iron was not obtained in winter, as compared with summer season, since the winter records show much less moisture in the atmosphere. The reason is that blowing-engines at blast-furnaces do not receive air of the dryness shown in the tables above. In summer the windows and doors of the blowing engine-room are wide open, and the humidity of the air supply is practically that of the atmosphere; but in winter they are nearly or quite closed, and the entering air has mixed with it all of the steam that leaks from the engine. Records taken over a number of years show that there is not a very great difference in the moisture in atmosphere between observations taken outdoors in summer and in the engine-room in winter. In Table VI. are monthly records showing a comparison between winter and summer months, the observations having been taken indoors and outdoors respectively.

From a comparison of Table VI. with Table II. it certainly appears that a material advantage could be gained by leading pipes from outdoors to the inlet-valves of the air cylinder.

TABLE VI.—*Moisture in Air in Winter and in Summer.*

Winter.		Summer.	
Month.	Quantity of Water per Cubic Foot of Air.	Month.	Quantity of Water per Cubic Foot of Air.
	Grains.		Grains.
January . .	4·5	April . .	4·2
February . .	4·6	May . . .	4·1
March . .	4·7	June . .	6·4
October . .	6·4	July . .	5·2
November .	4·6	August . .	6·7
December .	5·0	September .	5·7

So impressed did I become with this conclusion, that the blowing-engines at a furnace under my direction were thus equipped in the month of January, and continued to draw the supply of air from outdoors throughout the year. The excellent results expected in the winter season did not materialise, or rather, were so slight, as compared with a companion furnace not so equipped, as to argue against any further experiment in that line. This experience suggested the conclusion that while the air in the engine-room was higher in its content of moisture, through its admixture with steam, than the outside air, yet it was not subject to the same variations; and further, that these variations, which were often sudden and great, were really the most troublesome feature, and that nothing less than maintaining the atmosphere uniform with respect to humidity would prove of any material advantage. The saving in fuel through such uniformity could not be accurately set forth. The amount of fuel necessary for the decomposition of the moisture in the blast could be closely arrived at; but to what extent the reserve of heat, needed for counteracting the variations in moisture, could be diminished by desiccation of the blast, could only be approximately estimated in the absence of definite data. Nevertheless, the possible saving in that respect was deemed to be considerable.

Of course a wide field of experiment had to be covered in order to determine the most feasible method and apparatus for extracting the moisture. Various schemes for its direct absorption were worked out and in turn abandoned; and refrigeration

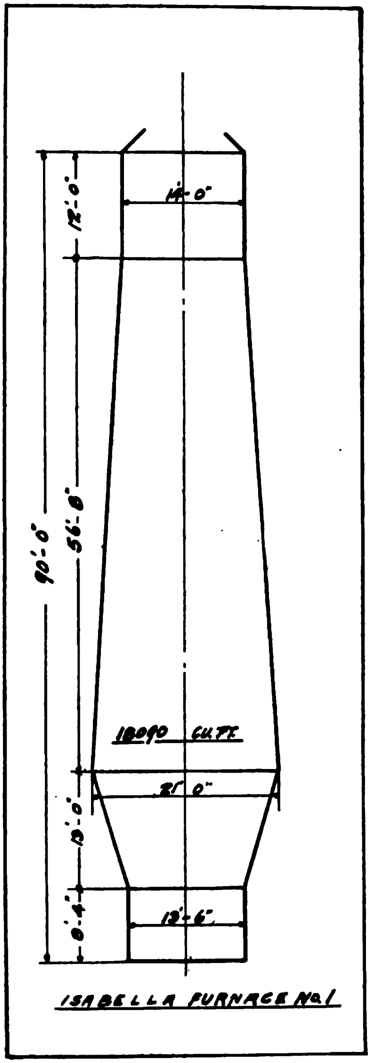


Fig. 1.—Lines and Dimensions of Isabella Furnace, No. 1.

by means of anhydrous ammonia was finally chosen. After many preliminary experiments an insulated chamber containing coils of pipe, and of sufficient size to treat the air from a blowing-cylinder 3 feet in diameter, was built. A small ice-machine was installed to circulate the ammonia through the coils, and the air was admitted to the refrigerating-chamber from an auxiliary chamber into which steam could be introduced at will, thus making it possible to treat, at any time, air containing the maximum amount of moisture with which it would be necessary to contend in the summer months. In this experimental plant air was treated under a variety of conditions for a considerable period, and from the data obtained the equipment for a modern furnace was worked out.

In the original plan, the refrigerating-chamber was placed between the blowing-engine and the furnace, so that the air passed through it under blast-pressure. At a furnace of modern type, this pressure may range from 15 to 30 lbs. per square inch —more than double that which was in use when this process was first conceived. In the practical working out of the process, it was found that workmen must frequently enter the refrigerating-chamber, to regulate the flow of the refrigerant through the pipes, and the thawing-off of the frost. A high pressure in the chamber would make its supervision and operation extremely difficult and hazardous. This consideration, together with that of the more expensive construction required by the high pressure of the passing air, led to the location of the chamber, so that the air should be drawn through it at atmospheric pressure to the blowing-engines.

The Isabella furnaces of the Carnegie Steel Co., located at Etna, Pa., a suburb of Pittsburg, were selected as the plant at which to install the apparatus for applying the dry-air blast.

The lines and dimensions of this furnace, shown in Fig. 1, represent the usual construction of furnaces in the Pittsburg district. The furnace is blown with twelve 6-inch tuyeres, and is equipped with four hot-blast stoves. Blast is supplied by three blowing-engines having the following dimensions: steam-cylinder, 44 inches in diameter; air-cylinder, 84 inches; stroke, 60 inches.

Fig. 2 shows in elevation the ammonia-compressors, condensers, and the refrigerating-chamber. This view of the refrigerating-chamber shows it to be connected for the direct expansion of ammonia; but as the escape of ammonia gas

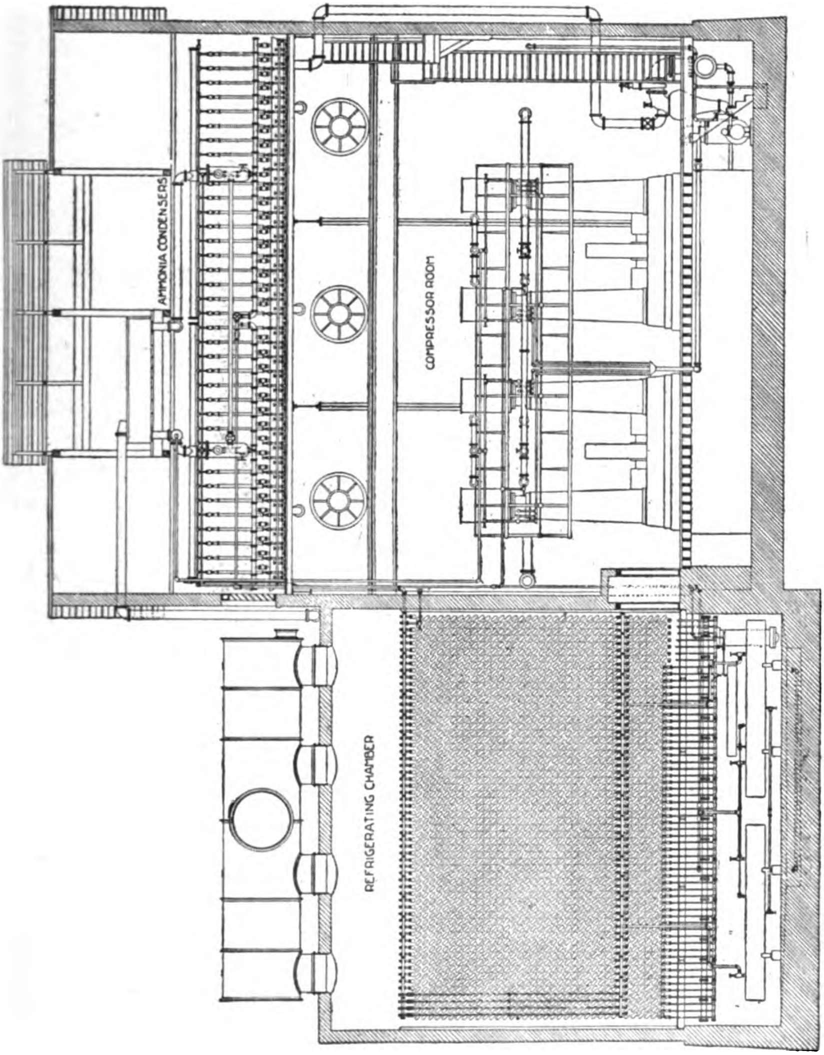


FIG. 2.—Compressors, Condensers, and Refrigerating Chamber (Side Elevation.)

through a broken pipe or leaking joint might imperil the life of any one in the chamber at the time, it was decided to adopt the brine system, and the pipe connections are as shown in Figs. 3 and 4, representing the refrigerating-chamber in end view and vertical section. The refrigerating-chamber is lined on the inside with plates of compressed cork 2 inches thick.

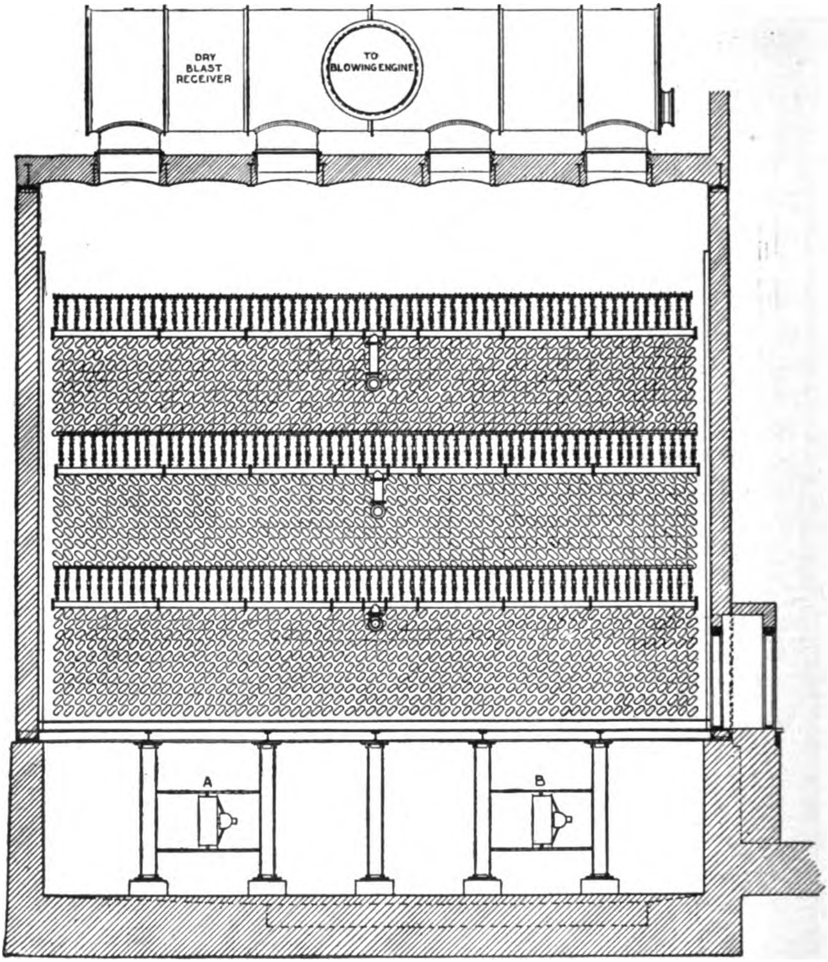


Fig. 3.—Refrigerating Chamber (Transverse Section).

The ammonia machines are of the compressor type, and were built by the York Manufacturing Co., York, Pa. The dimensions are as follows: diameter of the high-pressure steam-

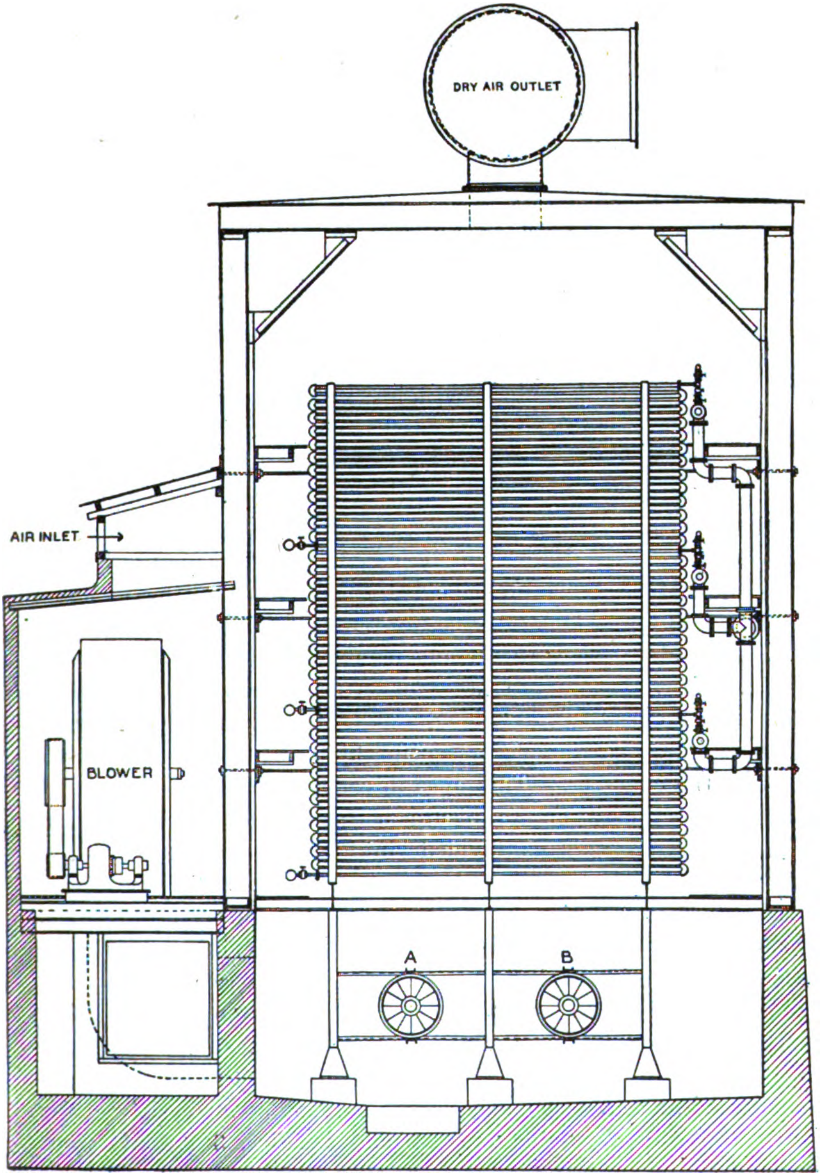


Fig 4.—Refrigerating Chamber (Longitudinal Section).

cylinder, 28·5 inches; low-pressure, 56 inches; compressor cylinder, 22·5 inches; stroke, 36 inches. Two compressors were installed in order to have one in reserve at all times, as a furnace operating on uniformly dry air cannot be subjected to ordinary atmospheric conditions without serious results, and frequently on very humid days the assistance of the second engine might be required. Each compressor has the capacity to melt 225 tons of ice.

Fig. 5 shows the brine-tank, containing twenty coils of pipe of the dimensions shown in the diagram. The coils are covered with calcium chloride brine having a specific gravity of 1·21. The return brine from the refrigerating-chamber flows into the top of the tank, is cooled by the ammonia expanding between the outer and inner pipes, withdrawn by a pump, and forced back through the pipe marked "brine inlet" into the 2-inch or inner pipes (where it is cooled below the freezing point), and thence into the coils in the refrigerating-chamber. The ammonia enters at the bottom of the pipes, thus travelling in the opposite direction from the brine, and by expanding between the 2-inch and 3-inch pipe, cools the brine, both in the tank and in the inner pipes; 40,000 gallons of brine are required in the system.

Figs. 3 and 4 show the arrangement of pipes in the refrigerating chamber. There are in each vertical line of coils seventy-five 2-inch pipes 20 feet long, and in the chamber sixty such vertical lines, the whole representing 90,000 linear feet of 2-inch pipe in the chamber. The pipes in each vertical coil are placed in staggered position to insure better contact with the air. The series of coils is divided into three sections, each fed through a 4-inch header, and discharging into a 6-inch header and thence into a standpipe, from which the brine flows to the brine-tank, the feed being arranged so that the brine flows in a direction opposite to that of the air. As the space between the pipes would become gradually reduced through the accumulation of frost, which might diminish the efficiency of the blowing-engine, a blower was installed to force air into the refrigerating-chamber; and in order to secure a uniform distribution of air over the coils, revolving fans (A and B, Figs. 3 and 4) were placed in the space underneath, so that all the coils would frost alike. The entering air, according to its humidity, deposits its moisture in the form of water or frost on the lower pipes and as frost only on the upper pipes, and passes from the top of the

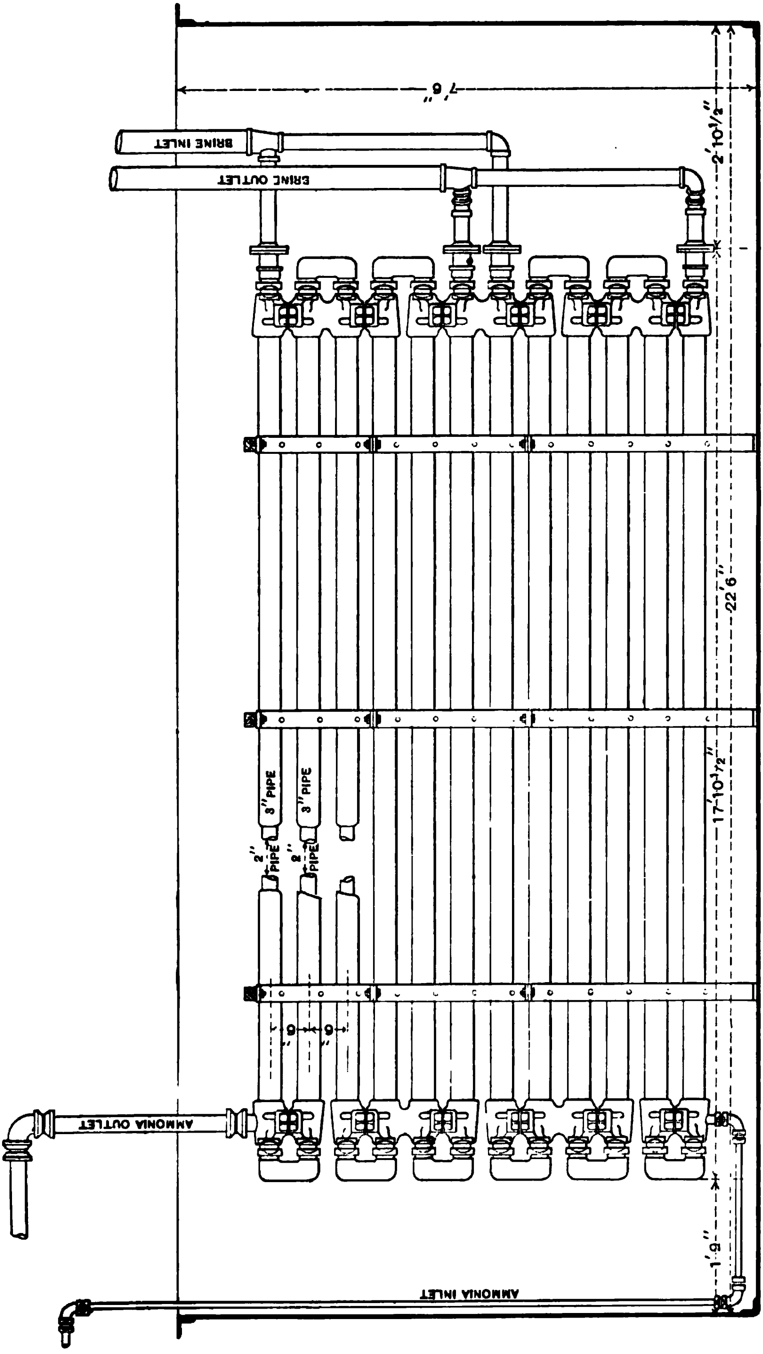


FIG. 5.—Brine Tank (Details of Coils of Pipes).

chamber to the blowing-engines at or below the temperature of freezing, and with a practically uniform content of moisture. When the pipes have become covered with frost the cold brine is shut off from several vertical lines of coil at once; by means of an auxiliary pump and line of pipe, brine that has been heated in a tank with steam is forced through; and in a few minutes the frost is melted. Connection is then made with the cold brine system, and frost begins to deposit quickly. The frost which has been melted off the pipes collects in a trough in the basement floor, from which it flows into the supply-tank for the condenser.

The plant is constructed throughout in the most substantial manner, for it is obvious that an apparatus treating such an important element of the process as the atmosphere could not be practically applied to a modern furnace in an experimental way, but must of necessity be as ample in capacity and as substantial in construction as any of the accessories of the furnace stack now in use.

In order to show the arrangement of different parts of the plant, four photographic illustrations are given. Fig. 6 shows the ammonia-compressors; Fig. 7 a view of the top of the brine cooling tank with its pipe connections; Fig. 8, the fans under the refrigerating coils, which are used to circulate the air; and Fig 9, the frosted ends of the coils in the refrigerating chamber.

This dry-blast plant was put in operation August 11, 1904. The furnace was making a grade of iron suitable for the basic open-hearth furnace, containing less than 1 per cent. of silicon, with an ore mixture consisting of 50 per cent. of Mesabi ore, the balance being soft hæmatites from Michigan. The mixture showed a yield by analysis of 53·5 per cent. of iron. The coke used was shipped from two mines, and varied considerably in ash. The quantity of ash present in these two coals averaged 10·5 and 12·5 per cent. respectively. In order to obtain correct data from the use of the dry blast, it was determined beforehand that no changes in any particular were to be made in the operation of the furnace, other than the introduction of dry air, and this has been rigidly adhered to. In the data following, a comparison is made between the operations of the furnace using dry air

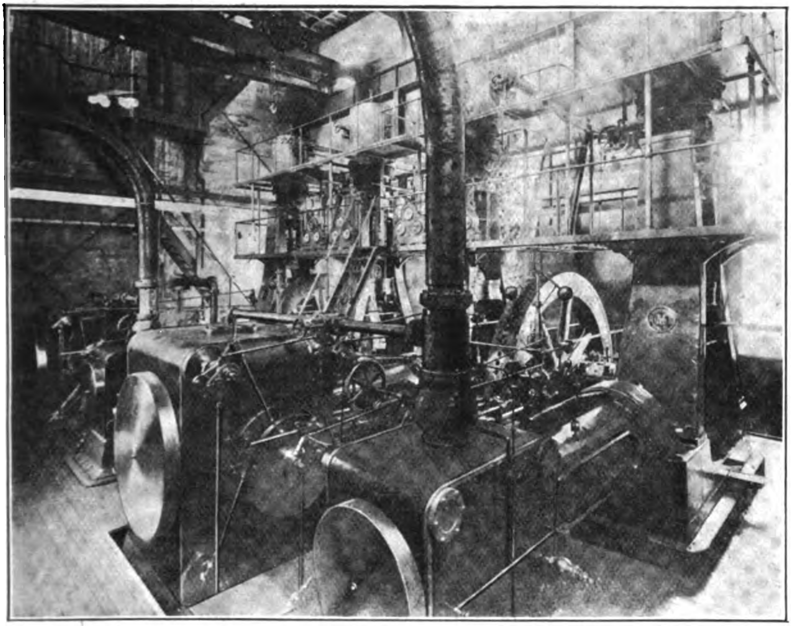


FIG. 6.—Ammonia Compressors.

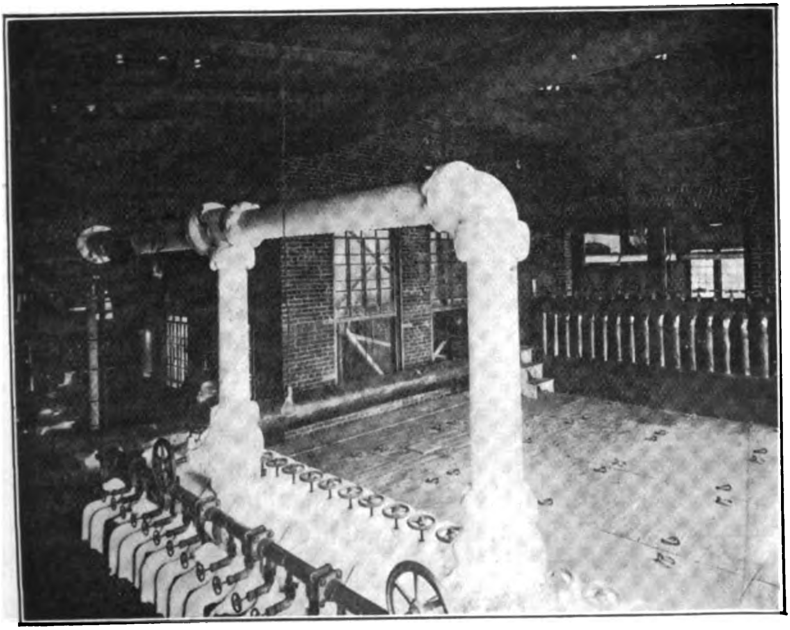


FIG. 7.—Brine Cooling Tank.

after August 11th, and those from August 1st to 11th, when the furnace was using the atmosphere under ordinary conditions. A comparison with the previous month would show a greater economy in coke, but since a change was made in the ore mixture in the latter part of July—which gave a lower coke consumption per ton of iron—a comparison of data when using dry air with that obtained in August prior to its use, and with the same ore mixture, would more accurately show the benefits derived. The burden on the furnace from August 1st to 11th inclusive was as follows:—

Coke	10,000 lbs.
Ore	20,000 lbs.
Stone	5,000 lbs.

On August 11th a 5 per cent. increase in burden was put on the furnace, and later in the day 33 per cent. of dry blast was used. As soon as this small quantity was introduced its effect was noticeable by a brightening of the tuyeres and an increasing temperature of the cinder. After this change in burden had come to work, the condition of the furnace being, if anything, still more satisfactory, an additional 5 per cent. of burden was put on, with confidence that an increased use of dry blast would offset the increased duty on the furnace. From this period on the burden and volume of dry blast were increased more slowly, until, on August 25th, the furnace using dry blast entirely had the following burden:—

Coke	10,200 lbs.
Ore	24,000 lbs.
Stone	6,000 lbs.

an increase in burden of 20 per cent. in two weeks. The record of the furnace from August 1st to 11th, prior to the use of the dry blast, and from August 25th to September 9th, inclusive, using all dry blast, is shown in Table VII. (p. 294). Fig. 10 shows graphically the record of furnace operations from August 1st to September 9th inclusive; the increase in output and reduction in coke consumption corresponding to the increase in burden; the varying conditions of humidity from day to day, which represent the average humidity for each twelve-hour period; and the change in humidity after treatment in the dry-

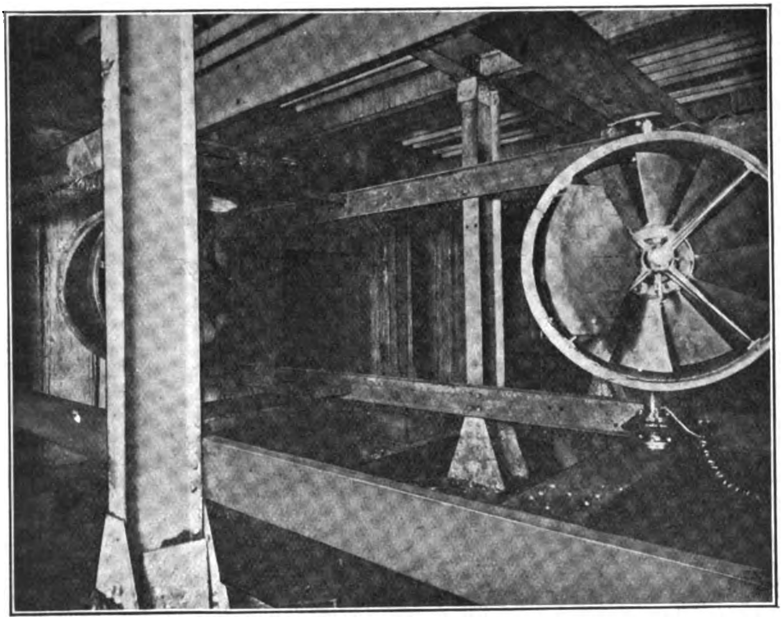


FIG. 8.—Revolving Electric Fans under Refrigerator Coils.

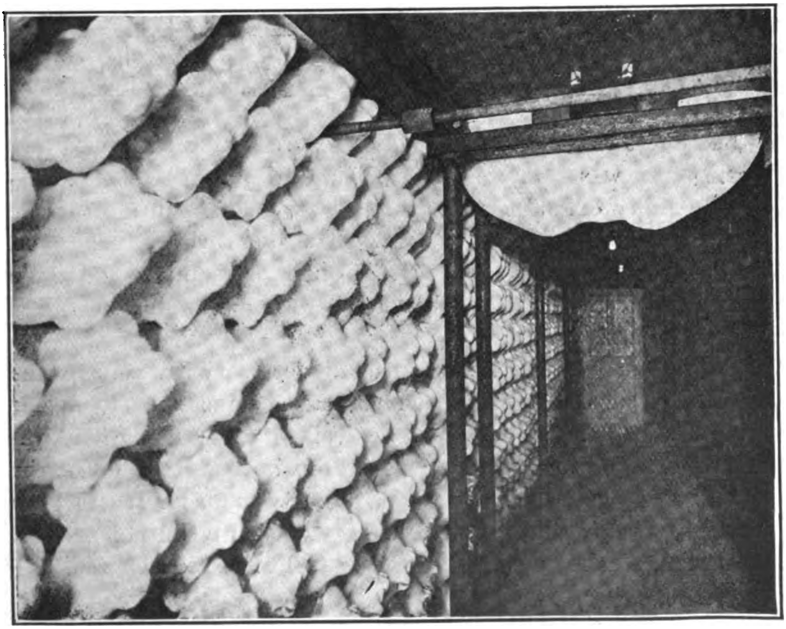


FIG. 9.—Frosted Ends of Coils in the Refrigerating-Chamber.

blast apparatus. While the reduction of moisture and its increased uniformity is considerable, it should not be lost sight of that this represents the beginning of operations, and there was still much to be learned with respect to the manipulation of the dry-blast plant.

TABLE VII.—*Furnace Records Without and With Dry Blast.*

Without Dry Blast.			With Dry Blast.		
Date.	Product.	Coke Consumption.	Date.	Product.	Coke Consumption.
	Tons.	Lbs.		Tons.	Lbs.
Aug. 1	360	2210	Aug. 25	462	1766
,, 2	367	2112	,, 26	441	1850
,, 3	372	2084	,, 27	477	1668
,, 4	373	2133	,, 28	516	1462
,, 5	386	2008	,, 29	405	1763
,, 6	340	2280	,, 30	441	1804
,, 7	347	2116	,, 31	462	1722
,, 8	360	2012	Sept. 1	472	1729
,, 9	378	2114	,, 2	472	1642
,, 10	352	2318	,, 3	458	1648
,, 11	306	2266	,, 4	421	1841
			,, 5	450	1813
			,, 6	400	1683
			,, 7	400	1734
			,, 8	397	1952
			,, 9	472	1642
Average . .	358	2147	Average . . .	447	1726

The effect of reducing and making more uniform the moisture in the blast, was clearly shown when, during a period of excessive humidity extending over three days, a neighbouring furnace charged during this period an extra quantity of coke and increased the quantity each day, in order to maintain the grade of iron, while the Isabella furnace, operating with dry blast, was in no wise affected.

On September 10th it was found necessary to make some repairs to the compressors and to make connections to a new brine-header for thawing-off the coils, and the burden was lightened accordingly. After these repairs had been made, the burden was again increased, and from September 17th to 30th inclusive, the furnace showed an average daily output of 452 tons, with a coke consumption of 1729 lbs. per ton of iron.

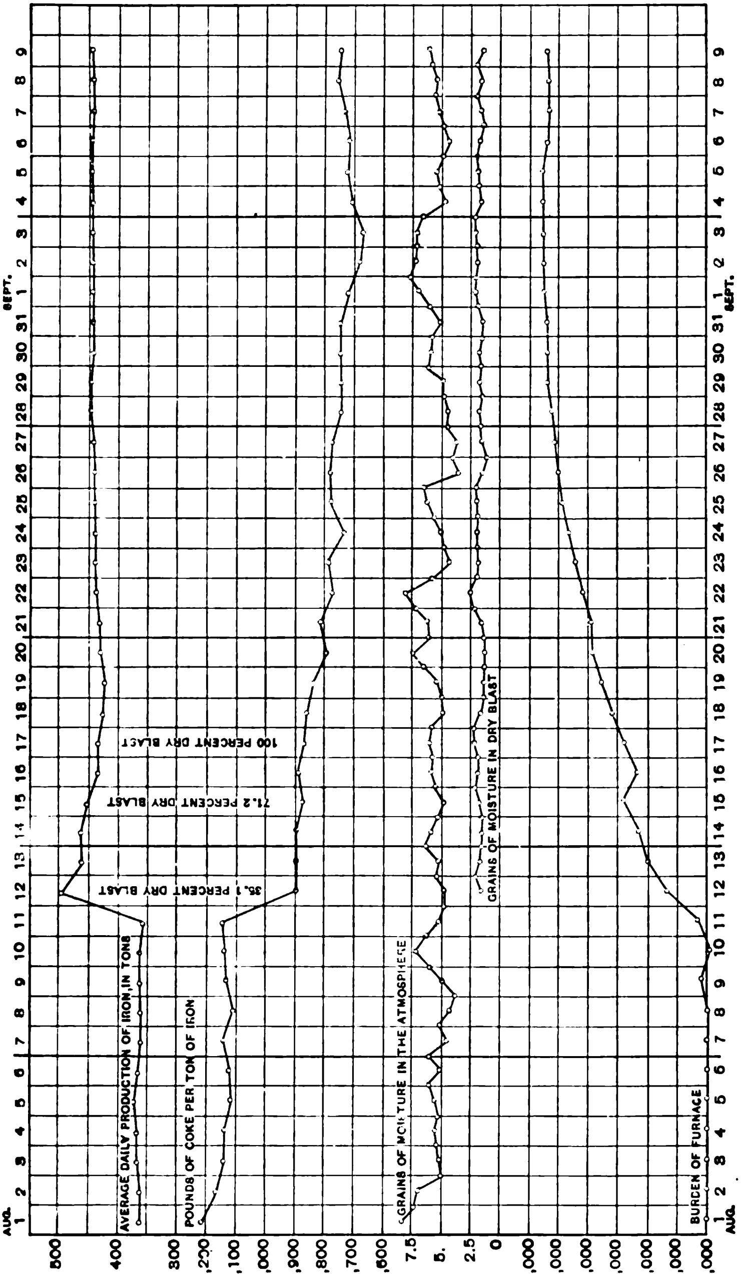


Fig. 10.—Record of Furnace Operations, August 1 to September 9, 1904.

Of the changes made in the atmosphere by passing it through a refrigerating-chamber, the daily records of operations, set forth in Table VIII., will give a very clear idea.

During thirteen days the average moisture in the atmosphere was 5·66 grains per cubic foot, and in the dry air 1·75 grains; 69 lbs. of water were removed from the blast per ton of iron produced, which represents an average of 23,192 lbs. (equivalent to 2784 gallons) for the twenty-four hours. This weight was calculated from the volume of air blown into the furnace, as shown by piston-displacement. For four days during the above period the water caught in the tank underneath the refrigerating-chamber amounted to an average of 21,561 lbs. (equivalent to 2588 gallons) for the twenty-four hours, which is as close an agreement as could be expected, considering that the figures do not represent the same number of days, and that it is difficult to

TABLE VIII.—*Refrigerating-Chamber.*

Time.	Temperature.		Grains of Water per Cubic Foot of Air.		Temperature.		Grains of Water per Cubic Foot of Air.		Temperature.		Grains of Water per Cubic Foot of Air.	
	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.
6 A.M.. . .	68	21	5·19	1·33	70	22	6·35	1·70	77	22	3·94	1·48
7 A.M.. . .	68	20	5·02	1·24	71	22	6·78	1·77	..	...	4·08	1·29
8 A.M.. . .	70	20	5·56	1·55	69	22	6·67	1·62	...	...	4·22	1·42
9 A.M.. . .	73	20	5·37	1·46	73	22	6·78	1·70	71	25	4·85	1·36
10 A.M.. . .	74	20	5·47	1·81	74	22	6·78	1·70	...	...	5·02	1·48
11 A.M.. . .	77	20	5·56	1·53	77	23	6·67	1·70	...	...	5·19	1·55
12 A.M.. . .	77	21	6·04	1·53	81	23	6·56	1·62	81	28	5·37	1·70
1 P.M.. . .	80	21	6·04	1·42	78	24	6·56	1·70	...	...	4·85	1·62
2 P.M.. . .	81	22	6·14	1·60	82	25	6·56	1·90	...	...	4·85	1·62
3 P.M.. . .	81	23	5·74	1·60	81	24	6·19	1·74	84	29	5·02	1·70
4 P.M.. . .	82	23	5·74	1·50	81	24	6·19	1·42	...	...	4·68	1·48
5 P.M.. . .	82	22	6·04	1·62	80	24	6·14	1·48	...	...	4·85	1·60
6 P.M.. . .	81	23	5·94	1·55	75	24	5·56	1·55	78	29	5·37	1·77
7 P.M.. . .	80	23	5·74	1·62	72	24	5·94	1·70	...	...	5·37	1·62
8 P.M.. . .	79	24	5·94	1·55	70	23	5·19	1·62	...	...	5·56	1·70
9 P.M.. . .	73	23	7·01	1·85	69	22	5·19	1·42	72	29	5·74	1·70
10 P.M.. . .	73	22	6·78	1·70	68	21	5·19	1·55	...	...	5·74	1·77
11 P.M.. . .	73	23	6·78	1·70	66	20	3·94	1·77	...	...	5·74	1·62
12 P.M.. . .	73	23	7·01	1·70	62	20	3·54	1·62	66	28	5·56	1·70
1 A.M.. . .	73	23	6·78	1·70	59	18	3·41	1·42	...	...	4·85	1·70
2 A.M.. . .	74	23	7·01	1·70	57	17	3·54	1·13	...	...	5·37	1·70
3 A.M.. . .	73	23	6·78	1·70	56	16	3·18	1·13	64	27	5·19	1·48
4 A.M.. . .	73	23	6·78	1·48	56	16	3·18	0·99	...	...	5·19	1·36
5 A.M.. . .	73	23	6·78	1·48	53	14	2·85	1·06	...	...	4·85	1·48

determine accurately the volume and humidity of the air supplied in a given period. It is found sufficient in practice to thaw the frost off the pipes every three days. The coils are divided, for the purpose of thawing-off, into three sections, each representing the same number of coils, and a section is thawed each day; and in this way the work of refrigeration is not interfered with.

When the dry blast was supplied to the furnace, it became necessary to reduce the revolutions of the blowing-engines, since the air supplied to the engines was lower in temperature than the natural atmosphere and contained more oxygen per cubic foot, and the tendency of the furnace was to drive too fast. Before applying the dry blast the engines were running at 114 revolutions and supplying 40,000 cubic feet of air per minute; the revolutions were gradually reduced to 96, thereby reducing the volume of blast over 6000 cubic feet per minute and increasing the efficiency of the engines by 14 per cent. With dried blast, 96 revolutions per minute of the blowing-engines burned nearly 1 per cent. more coke and produced 89 tons more pig iron in twenty-four hours than 114 revolutions per minute with atmospheric air. The reduction in the revolutions resulted in a gain of 150° in the temperature of the blast, which, even with this increase, through lack of area in the waste-gas ports of the stove, did not average above 870°.

The average analysis of the gas for ten days prior to the introduction of the dry blast showed: CO, 22·3 per cent.; CO_2, 13 per cent., with an average temperature of 538°. Later, with dry blast used entirely, the average analysis was: CO, 19·9 per cent.; CO_2, 16 per cent., with an average temperature of 376°. This reduction in temperature of 162° is a necessary consequence of the greater concentration of heat in the hearth by the dry-blast combustion and the greater weight of burden heated by the gas, and represents an important saving of heat in the furnace.

The dry blast has resulted in economies in several other directions. In the use of Mesabi ore, which is very fine in structure, the waste of ore dust carried by the escaping gases is very large, and at many furnaces it has become quite burdensome. At the Isabella furnace, before dry blast was used, it amounted to 5 per cent. of the ore charged; and it has been reduced, through the greater uniformity in the furnace working effected by the dry blast, to less than 1 per cent.

The saving in coke consumption reduces the phosphorus in the metal; and this, in making Bessemer iron, permits the use of ores higher in phosphorus. As the Isabella furnace was making basic iron, it was an advantage to keep the silicon as low as possible, provided the sulphur was kept low; and the absence of irregularities in the furnace operations resulting from the dry blast permitted the keeping of the silicon at a lower range without increasing the sulphur. It has been generally observed by furnace managers that when the silicon is lowered through increased humidity in the atmosphere, a leaking tuyere, or through other causes, the sulphur is rapidly increased; but it has been found in using the dry blast, that when the hearth temperature was suddenly lowered, principally from accretions on the bosh reaching the hearth, the sulphur did not increase; and in this respect the furnace has shown a remarkable uniformity in composition of the metal produced.

Mention has been made of the saving effected at the blowing-engines through a reduction in the number of the revolutions, which has an important bearing on the expenditure for power in operating the machines in the dry-blast plant. Prior to the use of the dry-blast plant, the average developed by each engine was 900 indicated horse-power. From the cards taken when the furnace was supplied with dry blast, this average was 671 indicated horse-power, a difference of 229 indicated horse-power per engine, or 687 indicated horse-power for the three engines. Cards were also taken from the ammonia-compressors, the compression and back pressure being kept as nearly as possible to the best working condition. Running at 45 revolutions, which would probably represent the average for the year, each engine developed 230 indicated horse-power, or 460 indicated horse-power for the two engines; the fans, together with the brine and water-pumps, are well covered by allowing for them 75 indicated horse-power, making a total of 535 indicated horse-power. Comparing this with the power saved in the blowing-engine room, there appears a net saving, after allowing for the operation of the dry-blast plant. These figures, however, may not represent accurately the difference in power consumption, as the blowing-engines were indicated at different times, and the first test was taken with a blast-pressure on the furnace of 17 lbs., while the test made with the dry blast was 15 lbs., and the figures given above might require some modification, as the effect of dry blast on blast-pressure is not yet fully determined. The increase of uniformity in the working of the furnace, obtained through the dry blast, would result in a decrease of the blast-pressure; and I think in any event the saving in power consumption in the blowing-engine room would nearly or quite compensate for the requirements of the dry-blast plant.

The application of the dry blast to the blast-furnace has shown, in addition to the economies effected, that the furnace can be controlled with precision; that it works with greater regularity; and that, in consequence, the product is uniform with respect to grade and composition, which makes the dry blast particularly valuable in the making of foundry iron, which is marketed by grade. An increase or decrease in blast temperature has a definite effect, and can be relied on to accomplish the desired result.

The dry-blast plant here described has been in regular operation since August 11, 1904. It started without a hitch, and no difficulties have developed in any direction. Some modification in construction has been indicated as the result of the operation of the plant, which would further reduce the moisture and add to its uniformity, but so far the changes suggested have been slight.

As above shown, the application of the dry blast to the blast-furnace has effected various economies and produced a more uniform metal. Probably its further application to the Bessemer converter would result in great benefit, since, in that apparatus, air is used in large quantities, and the varying humidity affects the temperature of the charge, and in consequence the quality of the steel. The metal from the metal-mixer employed in many Bessemer works is remarkably uniform; and the additional uniformity secured through the use of dry air would be of further advantage. In our American practice, a higher silicon is required in the summer months to maintain the temperature of the blow, in which period it is also more expensive to maintain the right amount of silicon in the pig iron. With the use of the dry blast in the converter the proper temperature could be secured with a lower silicon in the metal, and this in turn would further reduce the coke consumption at the furnaces. In other processes where air is used in large quantities—particularly in copper and lead-smelters and copper-converters, in the open-hearth furnace and in cupolas—it seems probable that the use of dry air would effect important economies, and its application to gas producers, by-product coke and charcoal-ovens, for the extraction of the moisture, would be very beneficial.

In the development of this process, which has occupied many years, during part of which time I was not directly in charge of blast-furnaces, much of the work has been necessarily entrusted to others. I desire to express my indebtedness to Mr. James Scott, General Superintendent of the Lucy and Isabella furnace-plants, and Mr. John P. Collins, Superintendent of the Isabella, for their valuable assistance in the application of the process; to Mr. Bruce Walter, Engineer at the works named, who conducted with great skill the later experiments, and supervised the construction of the dry-blast plant at the Isabella furnaces; and to Mr. John C. Greenway, then in the engineering department of the Duquesne steelworks, who conducted many of the earlier experiments.

DISCUSSION.

Mr. E. **Windsor Richards**, Past-President, said that in 1799 Mr. Dawson, of Low Moor, read a paper before a scientific society in York pointing out the great difference in the moisture of the air going into the blast-furnace in the hot months of the year and in the winter months. A cold blast-furnace was a very sensitive instrument, and showed this very clearly, for in June, July, and August the furnace did not drive so well; it did not make the quality of iron and required more fuel; so that Mr. Gayley was on the right road to effect an enormous improvement in this direction. He considered that Mr. Gayley was on the way to great success, and hoped that the apparatus would not be a very expensive one. He supposed it was too early for Mr. Gayley to let them know what the saving was likely to be. If they could produce pig iron considerably cheaper than was done at the present time it would be a great advantage to the trade, which was at present —on the other side of the water—in a somewhat unremunerative condition. He did not know whether Mr. Gayley would be able to give some idea of the cost of this apparatus or what it would cost per ton, and what the saving was likely to be. That information would be a very great benefit to those interested in the production of pig iron. Experiments had been made upon desiccation of air for blast-furnace purposes, but had hitherto failed owing to the enormous quantity of air to be desiccated. It seemed to him that it had been left to Mr. Gayley to solve this most difficult problem, and he congratulated him and the Institute upon the valuable paper which he had contributed.

Dr. R. W. **Raymond**, Honorary Member, said: Standing, as I now do, for the first time before the Iron and Steel Institute as a member of that body, I take this occasion to repeat publicly the thanks which I have already expressed by letter for the honour conferred upon me through my recent election to honorary membership. I was so stimulated by that experience that I determined, if possible, to get a copy of the precious first volume of the *Journal of the Iron and Steel Institute.* We had in the office of the American Institute of Mining Engineers two sets of that *Journal,* from both of which the first volume is missing. It is very difficult to persuade those who possess it to surrender it. But three days ago we came across a complete set; and we bought the whole for the sake of getting Volume I. As soon as the books came into our possession, I naturally examined that volume, and was well repaid; for I had the pleasure of reading the admirable address of the Duke of Devonshire, delivered in 1869, at the inaugural meeting of the Institute, in which he mentioned, among the important problems which at that time either seemed to have found solution or still remained to be solved, the effect of the moisture contained in the air of the blast, and varying at different seasons of the year—a problem which, by a happy coincidence, has been successfully treated, in theory and in practice, by the paper of Mr. Gayley, who is both a member of the Iron and Steel Institute and the President of the American Institute of Mining Engineers.

That society was organised in 1871, two years after the Iron and Steel Institute. I think all will admit that it has been a close second to you, in the investigation, discussion, and practical application of progressive improvements in the science and art of the metallurgy of iron and steel, and it is a great satisfaction to us that our President, in the paper submitted to you this morning, has answered (I think satisfactorily) one of the questions suggested thirty-five years ago by your first President, at your first meeting. Indeed, we feel that we may claim to have done, and to be doing, in this branch of scientific metallurgy, and for this country, at least, what the Iron and Steel Institute has done and is doing for the world. Or, perhaps, it would be more accurate to say, that we have supplemented, to the best of our ability, and not without success, the labours of your Institute, whose leadership we gladly acknowledge.

Not long after that memorable address of the Duke of Devonshire, some of the progressive blast-furnace managers of this country (among whom, as is shown by the pages both of the *Transactions* of our Institute and the *Journal* of your Institute, Mr. Gayley won long ago a high rank) began to consider what could be done in the way of desiccating the blast. I remember well a consultation on this subject with a young American manager, the practical result of which was the conclusion that the proposition was theoretically sound, but not likely to be practically economic, if attempted by the means then contemplated by us, and at the cost of installation then apparently necessary. But it does not surprise me that American ingenuity and audacity has since reversed that conclusion. In fact, the general belief that a thing is economically impracticable often has a fascinating effect upon ambitious minds (especially in this country, where exceptionally pressing conditions of competition, labour, &c., compel unceasing attempts at technical improvements); and Mr. Gayley, influenced by that stimulus, and aided by the improved modern devices for refrigeration, and by the means of testing his theoretical conclusions upon a practical working scale, has not only conceived the idea (as, no doubt, others had, more or less vaguely, done before him) but done the thing. The members of the Iron and Steel Institute do not need to be told that the first is comparatively easy, and that the second is the real achievement.

To my mind, this paper emphasises two propositions.

The first is, that great aggregations of capital may permit investigations and experiments too expensive to be undertaken by smaller establishments, and (what is equally, if not more, important) may save the time, labour, and cost which would otherwise be expended in parallel investigations, separately and even secretly conducted, each of which may fail of useful result, by reason of the lack of adequate support for conclusive tests upon a working scale.

The second proposition is, that great corporations, if they would justify their existence before the present and the coming generation, should make sure that their technical managers are both ready and able to discern the merits and encourage the development of inventions which will, by decreasing the cost or improving the quality of their products, confer lasting benefit upon the world.

Returning to the paper itself, I would call attention to what I regard as one of its most useful suggestions, namely, that the daily variation in atmospheric conditions is really more important in the running of a blast-furnace than the difference in such respects between summer and winter. In other words, we could prepare for more or less continuous conditions of any kind, even the most adverse. It would not be difficult, for instance, to operate a blast-furnace on the Equator, taking the blast from an atmosphere of unvarying temperature, and completely saturated with moisture. Having once determined the necessary fuel consumption, &c., we could accept the cost thereof as inevitable, and regard the results with equanimity, as the best that could be expected under the circumstances. Similarly, if atmospheric conditions varied only with the seasons, we could prepare for expected changes, and endure them with resignation. Indeed, if the variation of atmospheric moisture were confined to changes of season, it may be seriously doubted whether Mr. Gayley's apparatus would effect a sufficient saving to warrant the expense of its installation and maintenance.

But Mr. Gayley's exhibit of diurnal variations presents a consideration which, I must confess, seems to me much more important, even financially, and certainly so, when considered from the standpoint of a vigilant and anxious furnace-manager. For it was in my time, and I do not doubt that it still is, the sudden and inexplicable whims of the furnace—its changes without notice, and upon the same burden, blast and blast-temperature, which made the greatest economic trouble. We did not realise that the hygrometric variations of the air from hour to hour could account for such sudden changes; but in the light of Mr. Gayley's experiments, I think this may have been always the chief, if not the only, cause. The secret of successful furnace-management is like the secret of longevity. It is notorious that any list of centenarians will be found to represent all kinds of regimen: early rising, late rising; total abstinence, steady drinking; tobacco, no tobacco; meat, no meat; hot baths, cold baths; sedentary indoor life, vigorous out-door exercise, &c., &c. The only element they possess in common is regularity and continuity of practice. That seems to be an invariable element in long life, whatever else may co-operate with it. The man who changes his habits after he reaches fifty, is likely to die young! And since longevity is biologically an expression for a maximum of power and minimum cost of repairs, I think the analogy I have suggested is not fanciful, but real, and emphasises the corresponding principle in our (otherwise totally different) department. In my judgment, the hint in this direction afforded by Mr. Gayley's paper is not its least valuable feature.

Mr. E. P. Martin, Past-President, said the paper bore out very much what had been passing in his mind during the past ten or fifteen years with regard to the desiccation of blast applied to blast-furnaces. Every one had felt the difference of working blast-furnaces in summer and winter; but he thought Mr. Gayley had hit the nail on the head by pointing out that to obtain any real benefit the desiccation must be continuous and regular.

Mr. John Fritz, Honorary Member, said that this contribution was one of the most important he knew of in connection with the blast-furnace. Desiccation was always a matter of difficulty, and they never had had the courage or the money to do it. It was a great commercial problem. He considered that thanks were due to the Corporation with which Mr. Gayley was connected for furnishing him with the means of doing it. That required not only courage but a vast amount of money, and Mr. Gayley was to be congratulated upon his success. They had all thought of this problem and talked over it, but Mr. Gayley had done it.

Mr. G. S. Cook (Pottstown) said: I have been more or less interested in the subject of atmospheric moisture, as affecting the working of the blast-furnace, since 1888 or 1889. Mr. Gayley may remember the many conversations and discussions we had on this subject, when he was "a plain blast-furnace manager." Since 1890 we have been taking observations of the atmospheric moisture day and night at regular intervals, and so have collected a large amount of data, showing moisture per cubic foot of air, as related to the location of our blast-furnaces. The variations in the moisture furnished a key to, and explained many of the fluctuations to which the furnaces were subject. In connection with a well-known blast-furnace engineer, we sought a solution of the problem by the use of chloride of calcium. The idea was to have the engine connected with two structures containing chloride of calcium, so that as the air passed through, the moisture would be absorbed. When saturated, gas was to be used to dispel the moisture. Hence the necessity for duplicate structures, each fitted with pans containing calcium chloride, and provided with combustion chambers, for expelling the moisture absorbed. The cost of installing the plant, and of operating it, figured so high, compared with the fuel to be saved, that we gave up in despair. Mr. Gayley is to be congratulated upon the perseverance and ingenuity shown in carrying through to a successful issue a problem which others had recognised, but had considered impossible of solution, from a commercial standpoint. At Pottstown, located in the Schuylkill Valley, forty miles from Philadelphia, the records of the Warwick Furnaces show that at different seasons of the same year, as well as different years, the amount of water dissociated in the crucible of the blast-furnace, varies from 150 lbs. of water per ton of iron made, to as much as 450 lbs. We frequently find during the summer months 10 to 11 grains of moisture in the atmosphere per cubic foot of air. The moisture increases rapidly as the atmospheric temperature rises. The variation in the percentage of moisture we have found causes great changes in the working of the furnaces, bringing about many disturbances to regular and uniform working. Furnaces connected with plants making finished products will be the first to gain from the invention of Mr. Gayley, and I hope he will profit thereby. From the standpoint of merchant blast-furnaces, selling their product of pig iron in the open market, I can foresee a disadvantage. Ultimately the consumer will reap the advantage from decreased cost of manufacture.

The adoption of Mr. Gayley's improvement by one merchant furnace plant will compel its use by others, so that finally the invention of Mr. Gayley will add just so much to our investment, and leave us about where we were before, so far as profits are concerned. At a meeting in Philadelphia the week before of merchant blast-furnace presidents and general managers, the opinion was expressed that the merchant blast-furnace industry was the only one in which it was a crime to make any money, the idea of the buyer of pig iron being, apparently, that bare living was about all the blast-furnace man was entitled to. Whatever truth there might be in this remark, the fact is that for about every four years out of five the competition is close, and the margin of profit small, compared with the investment and the risk of operating furnaces. Once in a while, however, the merchant furnaces reap a harvest that enables them to recoup and improve their plants.

Mr. ANDREW LAMBERTON (Coatbridge) said that this most interesting paper appeared to him to describe what was a striking improvement in blast-furnace practice, and full of promise that the cost of production of pig iron would be substantially reduced by this invention. He would like to ask Mr. Gayley if one of the effects of the removal of the moisture from the air was that the hot-blast stoves were enabled to run for a longer period before changing over, and, if so, to what extent this was found to be the case.

Mr. E. H. SANITER (Rotherham) said that the subject was an extremely important one, but he did not propose to deal with the main point, but rather a side-issue, as he was not a blast-furnace man himself. Incidental reference was made to the Bessemer converter. He was informed in some plants when running with only half a per cent. of silicon sufficient heat was obtained. If they took the moisture out of the air, would they be able to make metal low enough in silicon to blow at a proper temperature? Dr. Raymond hit the nail on the head when he said that what was wanted was uniformity of the air, whether it was dry or moist. It might be necessary rather to reverse Mr. Gayley's process and to add moisture by some means so as to make the air uniform, rather than to desiccate it. The only other point was with reference to its application to the open-hearth process. That might also be very useful, but they would have to treat the greater sinner—the producer-gas, because it varied more in moisture than the atmosphere. Therefore they would have to deal both with the gas and with the air. In that connection it again came to a question of uniformity. If the Mond gas, which was now used for steel-making, were taken, it would be very regular although not very dry, and that would be a decided advantage. The drier the gas the better the heat, and in this connection the use of Mond gas was a distinct gain if sufficiently cooled.

Mr. A. SAHLIN (London) said that in 1895 he was connected with the Maryland Steel Company, whose works were situated on the shores of the Chesapeake Bay, below the City of Baltimore. That section was noted for the humidity of its climate, and the consumption of coke in the blast-furnace was accordingly high. Attention was directed towards a means for reducing it and for obtaining drier air.

Mr. Gayley had had a great advantage in his most interesting and seemingly revolutionising work. He had been backed by ample capital, by men of great enterprise, and had not had his authority curtailed by a board of directors, who perhaps were not always ready to recognise the difficulties of the blast-furnace man or willing to spend money in experiments to reduce the same. Therefore, Mr. Gayley had been successful in obtaining results; he had done what many of them had only been thinking of doing, and he should have the most cordial thanks and recognition from his co-workers in the industry which his work had benefited.

At the Maryland Steel Company's works, at the time mentioned, they had arrived at a very cheap device, which might be worthy of the consideration of some of those present. They had by analyses made clear the fact that the air inside of the blowing-engine house (which was large, containing besides the blowing-engines for the blast-furnace and the Bessemer steel works, pumping plant and air-compressing plant) always carried considerably more moisture than the outside air.

The more leaky the steam joints and the higher the temperature in the engine-house, the greater would be the difference in the moisture of the air inside and outside the building.

Therefore, at the suggestion of their President, Mr. F. W. Wood, they had encased the air cylinders of the blowing-engines in boxes connecting with the air outside the building. The result was a marked saving in coke, especially during the winter time.

Many of the smaller blast-furnace works would perhaps be unable to control the capital necessary to instal a refrigerating plant, such as Mr. Gayley had designed, whereas everybody would have a chance to build a rough box of boards around the blowing-cylinders, and he thought that the benefit derived, especially in humid climates, would amply pay for the trouble taken.

In conclusion he took pleasure in endorsing the opinion of previous speakers as to the great importance of Mr. Gayley's method, and felt convinced that it would put within their reach hitherto undreamt of economies in coke consumption.

CORRESPONDENCE.

Mr. W. J. Foster (Darlaston) sent the following communication: The question of the desiccation of that portion of the atmosphere which is necessary for the oxidation of the carbon in the hearth of the blast-furnace by means of refrigeration, will no doubt attract the special attention of blast-furnace managers in the future, especially in those places where the air required per unit of iron made is large, as compared with some furnaces which are working on more modern lines. It is quite evident that the plant that will be necessary for the desiccation of the great quantity of air required for the production of pig iron, will necessarily be of an elaborate nature, depending to a great extent on the cooling surface of the refrigerating chamber, and the particular method of insulation, just as a boiler depends on the heating or cooling surface, assuming that the fall in degrees of temperature in both cases are the same; but, of course, in the case of refrigerating the atmosphere the difference in the temperature of the ingoing air and the temperature of the refrigerating chamber is not so great as would be the case when dealing with the combustible gases in boiler practice, hence a corresponding reduction in its efficiency per unit of tube area. These conditions are based on the fact that the tubes will not conduct or neutralise the heat so rapidly with bodies at nearly the same temperature as would be the case with a great difference in the temperature of the matter inside and outside the tubes respectively. These circumstances will, of course, necessitate the erection of a plant of an elaborate nature; nevertheless, I am of opinion that the refrigerating system is by far the best method up to the present suggested for eliminating the aqueous vapour from the atmosphere.

Previous writers on the hot-blast theory tell us that the increased coke consumption which is due to the water or aqueous vapour entering the furnace is equivalent to the direct proportion of the heat necessary to decompose the water molecule. By referring to my paper of May 1904 on the efficiency of the blast-furnace it will be seen that when dealing with the hot-blast question and the cooling effect of the aqueous vapour in the circumstances that were existing at the Darlaston No. 1 furnace the calculations were simply based on the heat necessary to decompose the water molecule, minus the heat which is given to the aqueous vapour due to heating the blast only represented a saving of 0·478 cwts. of coke per ton of iron, with a total coke consumption of 29·2 cwts.

A careful examination of my remarks on this subject will show that the above quantity of coke is not the quantity that would actually be saved, but on the other hand it is clearly shown that by effecting a saving in this one item by increasing the temperature of the blast we would also have a saving in every other branch of the system, with the exception of the parts clearly defined, the total of which only represents 6·646 cwts. of coke, this being a quantity that is absolutely necessary in these parts of the process which it represents, and the remaining items which correspond to 22·544 cwts. of coke would be indirectly effected by either the superheating of the blast, or any method that would have an influence on the partial removal of the aqueous vapour or its decomposition before entering the furnace. The abnormally high fuel consumption represented above is chiefly due to smelting silicates of iron with low blast temperature, &c., and was instanced specially to illustrate the hot-blast theory: the results are very different when working with other materials.

The furnace using the largest quantity of air per unit of iron made, such as is the case in cold-blast practice, will undoubtedly have proportionately a greater advantage of the use of dry air than those using a less quantity. As previously mentioned, the saving will not be found in direct proportion to the air used, but will be found to realise very much greater advantages.

It is quite certain that the adoption of any practice that will prevent water or water vapour entering the furnace at the hearth will without doubt be found to have a great advantage in furnace practice, under the conditions under which they worked at Darlaston. I have estimated that the quantity of heat units necessary to heat the blast to 454·4° C. is equivalent to 2·075 cwts. of coke (measured by the simple complete combustion of carbon and consequently based on the previously recognised hot-blast theory), and the heat necessary to decompose the water vapour was found to be 0·478 cwts. of coke, but in practice I find that this would be equal to at least 10 cwts. in the case of heating the blast to the temperature mentioned, &c., consequently the saving of fuel by removing the whole of the moisture would be represented as follows:—

$$2{\cdot}075 : 0{\cdot}478 :: 10 :: 2{\cdot}336$$

which shows a saving of 2·336 cwts. of coke per ton of pig iron produced. It will be seen that, taking the figures mentioned above, and assuming that the whole of the moisture is eliminated, also putting the average cost of fuel at 14s., which is equivalent to 1·61 shillings per ton of iron, and allowing 20 per cent. for working expenses and depreciation of plant, &c., estimated on 600 tons of pig iron per week, the approximate saving in round numbers would represent a dividend of 10 per cent. per annum on a capital outlay of £20,400. From the data describing the practical results in the author's paper it appears that Mr. Gayley has solved a very difficult problem.

Professor H. M. Howe (New York) wrote that the value of Mr. Gayley's invention was so great that one could hardly rate it justly without danger of seeming theatrical. When we considered the greatness of the pig-iron industry, even the minor advantages of the process such as the saving of fine ore, the raising of the phosphorus-limit of the ore, and the better control over the sulphur and silicon contents of the pig iron collectively were of enormous value; but passing these by, the fuel-economy reported fairly took one's breath. Assuming that the world's annual output of pig iron was, roughly, 46,000,000 tons, and that it called for some 46,000,000 tons of coke, representing some 66,000,000 tons of coal, Mr. Gayley's saving of 20 per cent. as shown by his exhibit VII. would correspond, if applied to all the furnaces of the world, to no less than 13,000,000 tons of coal per annum, or more than twice the total annual coal production of New South Wales, and more than half that of such important coal-producers as Belgium and Russia. We hardly expect this invention to be used at every furnace at home and abroad; yet when we remembered to how great a proportion of all the furnaces of the world Neilson's invention of the hot-blast had been applied, there was very little fear that any large fraction of the world's furnaces would fail to adopt the dry-blast sooner or later.

His remark in the last paragraph but one, that the dry-blast plant "started without a hitch and no difficulties have been developed in any direction," would not greatly surprise those familiar with his exploits.

Refrigerating processes evidently had a great future. It was not necessary to consider such obvious uses as cooling dwellings and factories in hot climates, though failure to do this would, to the future historian, stamp this age as among the barbarous ones. But there was a use which was of interest to those who speculated as to the future of the iron industry. Not a few at this meeting had said with Burns—

"And forward, though I canna see,
I guess and fear."

At first sight it certainly might seem that the supply of iron ore, finite as it was, and not reproduced like our animal and vegetable supplies, would exhaust itself, not indeed in our time nor that of our children, but long before the other great staple materials of industry, such as wood, the textile substances animal and vegetable, bread stuffs, meat, and other foods. Yet, on reflection, this idea lost its force; for if the earth really was an enormous meteor with but a relatively thin crust of rocks, there was a supply of iron which would last long after the earth had ceased to be habitable. We depended upon the forests and green fields for our supply of oxygen and of food; but when sun and earth should have so far cooled that the ice-caps spreading out from either pole finally met at the equator; when Mother Earth, exhausted, drew together those icy curtains for her endless sleep, where would be the fields and forests to give us the breath of life? Would not our atmosphere then be one of nitrogen plus carbonic acid, and the earth a desert?

But how were we to attack and reach this iron nucleus of the earth? Clearly through these refrigerating processes. When man should have exhausted the limited, and hence exhaustible, deposits of the earth's crust, knowing the vast central mass of iron beneath him, he would be forced to find a means of freezing his way to it.

Mr. V. Pendred (London) wrote: Mr. Gayley appears to have assumed, on very inadequate grounds, that moisture in the atmosphere plays an important part in the performance of a blast-furnace. How he has arrived at his conclusions I am unable to say. To simplify matters and in the end save space, I give here the only passage in the paper which sets forth the reasons which led him to make the interesting and valuable experiment which he describes. "The desiccation of the air used in blast-furnaces in such a way as to reduce its moisture to a small quantity, and to keep it uniform, must of necessity contribute in a very marked degree toward the attainment of uniformity in the furnace operations. The advantages from desiccation can be appreciated only after due consideration is given to the volume of air that is consumed per minute, and the large amount of moisture which it contains. Managers of blast-furnaces are familiar with the chilling effects produced in the hearth by a tuyere that is leaking, which immediately results in a deterioration in the grade of the iron; yet the quantity of water ordinarily entering the furnace under these conditions is not greatly in excess of the quantity carried in, like a steady stream, by the atmosphere, during a period of the average humid conditions prevailing in the summer season in this country." Now I hold that although Mr. Gayley's results are satisfactory, the reasons which he gives for the success which he has attained are entirely wrong. It is evident that he has taken it for granted that water is carried into the blast-furnace with the blast. This might happen provided the blast was cold; but as a matter of fact it was heated for the Isabella Furnace to somewhere about 800 degrees Fahr., at which temperature, and some six or eight pounds above atmospheric pressure, water could not exist as such. Under normal conditions damp air is delivered to the stoves, not to the furnace. The moisture is at once converted by the red-hot bricks or pipes into superheated steam. The quantity is very small. It remains for Mr. Gayley to show what part it can play in the extremely complex reactions going on in the blast-furnace. On this aspect of the case he is entirely silent. Furthermore, it may be pointed out that the ore, as it comes from the bins, is always damp or even wet, and that the weight of water introduced in this way into the furnace is out of all proportion greater than that of the superheated steam gas, which goes in with the blast. So far my contention is negative. That is to say, I hold that the moisture in the air could have no appreciable effect on the make of iron, either chemically or thermo-dynamically.

I now wish to show why the output of the Isabella Furnace was so much increased by refrigerating the air. Good was done, not by drying the air, but by augmenting its density by cooling it. Let us suppose for the sake of argument that, the pressure remaining at 14·7 pounds and the temperature 62 degrees Fahr., one pound of air has a volume of only 6·57 cubic feet instead of the normal 13·14 cubic feet. Then, the blowing-engine remaining unaltered as to size, and running at the same speed, it will deliver per minute twice the weight of air. The work done by the engine will be the same. All the ports and passages will still be adequate. But the rate at which the furnace works depends not on the volume of air blown into it but on the weight of oxygen passing the tuyeres every minute. Under the new conditions, everything else remaining unaltered, we should double the output of the blowing-engines, and, under suitable charging and tapping conditions, that of the furnace. Unfortunately, hitherto the iron master could not increase the weight of his blast nor augment the weight of oxygen passing the tuyeres without running his blowing-engines faster. Mr. Gayley has shown us, however, how a very important advantage may be gained in this direction. Let us suppose that he was blowing, normally, at 70 degrees Fahr., that being the inhaling temperature of the blast tubs. Then each pound of air would have a volume of 13·342 cubic feet. If now, by refrigeration, he reduced the inhalation temperature to 40 degrees, then each pound of air could have a volume of 12·586 cubic feet only, and the weight of air sent into the stoves under the two conditions would—the blast-engine running unaltered—vary in the inverse ratio of the two pressures. In other words, the efficiency of the blowing apparatus would be increased by, say, 6 per cent. But we know that Mr. Gayley was on many occasions able to work with much larger temperature differences than these. Thus the inhalation temperature has been reduced from 82 degrees to 23 degrees, at which in round numbers the volume per pound are to each other about as 13·6 is to 12. In this case the efficiency of the blast-engines was augmented by about 13 per cent. This is the reason why Mr. Gayley had to reduce the number of revolutions. Indeed, he has recognised the truth, although he does not attach due importance to it, for he says on page 297 of the paper, "When the dry-blast was supplied to the furnace it became necessary to reduce the revolutions of the blowing-engines, since the air supplied to the engines was lower in temperature than the natural atmosphere and contained more oxygen per cubic foot, and the tendency of the furnace was to drive too fast." Nor is it to be supposed that the advantage gained was represented wholly by the percentage I have given. Any one familiar with blast-furnace working knows that an augmentation in blast density produces effects larger in proportion than could be anticipated. I have not thought it necessary to go into any detailed calculations. I hope I have said enough to make my meaning clear. The gain derived from refrigeration would have remained about the same if the water had not been removed at all, provided, of course, that the stoves were of sufficient power. At the Isabella Furnaces they appear to have been deficient, and the augmented blast density helped them on the one hand, while they were spared the loss of a little energy in converting water into superheated steam. Finally, I can assure Mr. Gayley that I have read his paper with much pleasure, and regard it as a most valuable contribution to our *Journal.*

Mr. B. H. **Thwaite** (London) wrote as follows: Regarding the characteristic defects of modern blast-furnaces, the supremacy of control over the character of the operations and products of a blast-furnace has been advanced by the important success of Mr. James Gayley's enterprise and ingenuity.

It has often been claimed for the blast-furnace that as an instrument of industry it has attained a rare degree of perfection and efficiency, but in recent years it has been demonstrated that a wide margin still exists for further improvements, and especially in methods of thermal utilisation. The margin has, however, been greatly reduced by the harnessing of the gas-engine to the blast-furnace. Again, the hot-blast stove efficiency is far too variable, and the contributor, along with others, is attempting to remove this element of thermal inefficiency and irregularity. An ideal blast-furnace operation would be one in which all the agents required for the production of iron are perfectly controllable in character, in application, and in proportion. But we know that the hygrometric condition of the air is constantly changing, and this variation, added to the vagaries of the thermal output of the hot-blast stoves, is responsible for many of the annoying irregularities in the working of the furnaces. Close observers of blast-furnace operation phenomena have long ago recognised, in perhaps an imperfect measure, the extent of the influence of the hygrometrical or water content variation of the air on the working character of the blast-furnace, but it remained for Mr. Gayley to measure more or less exactly the influence, and at the same time discover a practical means of regulating and reducing the proportion of water introduced in the air-blast into the furnace hearth.

In the period of inception of his refrigerating air-drying system, Mr. Gayley would no doubt be told that the loss of thermal energy involved in his system would probably more than counterbalance the advantages to be derived in reducing to a fixed degree the moisture in the atmospheric air required for furnace operations. To his great credit, Mr. Gayley has had the courage to balance the thermal loss and gain by an actual test on a large and expensive scale, and the balance appears to have splendidly justified the test.

The introduction of water into the furnace hearth, whether in the form of aqueous vapour or directly from tuyere leakage, has the following chemical sequence when in contact with iron. The equation is $4H_2O + 3Fe = Fe_3O_4 + 8H$; in contact with the carbon of the fuel the equation is $H_2O + C = CO + 2H$.

The absorption of thermal energy in the dissociation of H_2O reduces the furnace hearth temperature; and although the re-oxidation of the hydrogen in the hot-blast stoves and in the steam boiler furnaces restores part of this thermal loss, there is always in the use of hydrogen the irrecoverable loss of the latent heat of steam formation—unless methods of condensation, or temperature reduction below 212° Fahr., are available, which for stove and furnace gases they are not.

According to Mr. Gayley, the operation of the refrigerating machinery involves the expenditure of 535 indicated horse-power.

The writer demonstrated, many years ago, that if the blast-furnace gas was used directly for the production of the power, the output would be increased some 400 per cent.; but, assuming only a factor of 300 per cent., there would be an excess of power available by the displacement of the three steam blowing-engines of 671 indicated horse-power of not less than $3 \times 671 = 2013$ indicated horse-power; so that the question of additional power supply need not influence the decision as to the wisdom or otherwise of adopting the dry-air process once the complete adoption of gas power is also agreed upon.

In the power expenditure data supplied by Mr. Gayley there is perhaps some miscalculation; the mystery is, however, partly cleared up by the reduction in the resistance of the furnace burden and the reduced volume of air = represented by the fall of the blast pressure by 8·8 per cent.

The calorific value of the blast-furnace gas of 22·3 per cent. of CO in using dry air is reduced by 2·4 per cent. or to 19·9 per cent. in the absence of the hydrogen data; the calorific value of the gas cannot be determined, but it will probably not exceed 75 to 80 B.T.U. per cubic foot. This gas, both for stoves lighting from the cold or for steam raising, will be very deficient in igniting qualities, and it would be interesting to hear whether this gas is used for steam raising, and whether any auxiliary fuel is required to sustain ignition. The gas is quite suitable for use in specially designed gas-engines, and its calorific reduction could be still further extended without risk of destroying its power-producing usefulness.

Advantages and Disadvantages of the Dry-Air System.

Debit.	Credit.	Credit Balance.
Thermal loss in compressing air. Ditto in lowering temperature of air some 53° Fahr. Reduced calorific value of gas. Reduced sensitiveness of gas to ignition. Capital expenditure in refrigerating plant and cost of supervision and stoves relating thereto.	Greater density of refrigerated air involves less blowing-engine power to provide same weight of air-blast. Less resistance to flow of gases through furnace burden, owing to more equable and uniform working conditions. Greater control over furnace operations and its product, especially in proportion of silicon. Reduced iron ore waste.	20 per cent. greater output of iron. 20 per cent. reduction in fuel consumed per unit of pig iron and output. Reduced iron ore waste and greater control over silicon range.

On the basis of Mr. Gayley's figures representing the economy to be secured by the use of dry air, and assuming the variation of moisture in the atmosphere between the winter and summer months to be within the limits indicated in the graphic diagram, Fig. 1, it is possible to calculate the economy that should be obtained in a furnace, released from an environment of steam issuing from blowing-engine pump and hoisting-engine and shunting locomotive exhaust-pipes, and the escaping steam from steam-boiler safety-valves, all changes resulting from the supersession of steam by gas power. It may also be assumed that the tuyere water is cooled, without adding to the air moisture content, and that the chilling of the pigs does not involve any material production of steam or water vapours. Taking the average proportion of moisture in the winter months of November, December, January, and February to be equal to 2·15 grains per cubic foot, this proportion, compared with that of summer months' average, is only 73 per cent. less than the average content of refrigerated air in Mr. Gayley's reported tests. Now the average increase in pig-iron output as the result of using dry air equals 20 per cent., and, curiously enough, the reduction in fuel (coke) is represented by the same figure. Therefore, furnaces working in the four winter months named, and in a completely steamless environment, and all other conditions being equal, should give an increased efficiency represented by 14·6 per cent. In other words the pig-iron output in November, December, January, and February should be 14·6 per cent. greater, and the fuel consumption per ton of pig-iron output should be 14·6 per cent. less than the results of the four summer months of June, July, August, and September. There is in these possible winter improvements in output and fuel economy an adequate *raison d'être* for the supersession of steam by gas power, a technical reform that would add to the advantages claimed for the dry-air blast, because—

1st, The evils of escaping steam into the atmosphere would be removed; and

2nd, There would be an ample supply of power available for air compression and air refrigerator services.

Mr. GAYLEY, in reply, said: With reference to one question that had been asked, as to the changing of the stoves, he would state that there had been no change in their operation. The practice at the Isabella Works, having four stoves to the furnace, was to have one stove on blast and three on gas, changing stoves every hour. Mr. Saniter had said that he understood, with respect to their Bessemer practice, that his firm was hoping to run with ½ per cent. of silicon; no doubt this could be done if the dry-blast were used at the Bessemer department, and by such use a further economy in coke could be obtained at the blast-furnace, but in their practice at the present time, with the use of mixer metal, the silicon content was from 1 to 1¼ per cent. Mr. Saniter was quite correct in calling attention to the importance to the open-hearth furnace of extracting the moisture from the producer-gas. He (Mr. Gayley) was confident that if the moisture were extracted from both gas and air for use in the open-hearth furnace, and from the air supplied to the converter, it would result in increased product and greater uniformity in the metal. A question had been asked by Mr. Windsor Richards as to the saving obtained by this process. That, of course, varied with each locality, but he had given data from which the economy for any one district could be calculated. It had been found, as a result of several tests, that the saving in horse-power in the blowing-engine room practically compensated for the expense of operating the dry-blast plant. They had found through the use of this process a saving in coke, labour, supplies, and general expenses, in the limestone corresponding to the coke saved, which would otherwise have been needed for fluxing the ash, a reduction of phosphorus in the metal corresponding to the reduction in coke consumption, which was of some importance in the making of Bessemer pig, and, where fine ores are used, there was less waste of ore through furnace gases. In addition to this there was increased earning capacity for the plant through increased output.

In preparing this paper he had only been able, by reason of the limited time permitted in its preparation, to present a description of the process with the results obtained therefrom, while there were many questions relating to the economy effected which would have to be considered later. In the meanwhile it had transpired that certain statements made in the paper had been misunderstood, and he took this opportunity to shed further light, if possible, on some of them. First, with regard to the density of the blast; some erroneous calculations might be made from the data showing the air entering the refrigerating chamber at about 80 degrees and leaving it at about 25 degrees, since the dry air in passing through the main from the refrigerator to the blowing-engines was increased in temperature to 35 degrees Fahr. From a careful indicating of the engines it had been found that there was 8·2 per cent. less weight of air entering the furnace than had been used prior to the introduction of the dry-blast. Next, with regard to the moisture contained in the atmosphere. It had been assumed to be a matter of common knowledge that the moisture in the air was contained as aqueous vapour, and when passed through the stoves became superheated steam, and whether the moisture entering the furnace as superheated steam with the blast, or as water from a leaking tuyere which was at once converted into superheated steam, it was nevertheless a form of water, and that it must be dissociated by the fuel and heat absorbed; but inasmuch as there was superheated steam to deal with at one end of the process, and frost or snow at the other end, it had been deemed preferable, as stated in the beginning of the paper, to represent the moisture contained in the atmosphere as grains of water per cubic foot of air.

In the paper presented to the Institute he had simply given the results obtained by the use of dry air, and without any intention of claiming that the economy in fuel was represented entirely by the weight of moisture eliminated. It would require a very simple calculation to show that it was not. The calculations covering a period of operation showed that the saving, directly due to the removal of moisture, represented 24 per cent. of the total fuel saved. But a far greater economy was effected in the use of the dry-blast, and was represented by the reduction in temperature of the escaping gases, and the greater efficiency in the reducing gases as shown by the increase in percentage of carbonic anhydride. These items alone would account for one half of the saving in coke. In addition to the items already mentioned there was a material saving through the increased temperature of the hot-blast, a lowering of silicon in the metal, and in a smaller amount of slag to be melted, as less coke was required per ton of iron.

The moisture charged into the furnace through the raw material was many times greater than would enter the furnace from the atmosphere; but to get rid of it through simple evaporation by gases which had already performed their useful work, was quite a different proposition from that of dissociating the quantity of moisture carried in from the atmosphere into the hearth of the furnace where temperature was such a vital element.

During the month of December there had been an excellent opportunity of noting the results obtained by the use of dry-blast, as Nos. 1 and 3 furnaces at the Isabella plant (No. 2 furnace having been out of blast) were making the same grade of iron. These furnaces were nearly the same size, No. 3 being a little larger. The same ore mixture and fuel were used in each furnace, and the conditions under which they were operated were identical. No. 1 furnace was blown with dry-blast containing 1 grain of moisture per cubic foot of air, while No. 3 furnace used natural air, which, being drawn from the engine-room, contained from 2 to 4 grains of moisture. Although this period represented the best conditions as to dryness of the air in that climate, and furnaces under ordinary conditions increased decidedly in output above the average, yet the results obtained from a small and uniform content of moisture in the dried air supplied to the blowing-engines, in contrast with the varying content in the atmosphere, were very striking. From December 1 to 22, inclusive, the results were as follows:—

	No. 1 Furnace, Dry-Blast.	No. 3 Furnace.
Average daily product . . .	449 tons.	400 tons.
Average coke consumption . .	1858 lbs.	2309 lbs.

As connections had been made to the dry-blast main for four blowing-engines, and as only three had been used on No. 1 furnace, it was decided to connect the fourth engine to the main, and supply No. 3 furnace with one-third dry-blast. This was done on December 23, and it was decided not to make any increase in the burden or to change the revolutions of the blowing-engines, in order to see what effect the use of approximately one-third dry air would have on the output of iron. The furnace immediately began to drive faster, and the average daily product from December 23 to 31, inclusive, was 461 tons, an increase of 61 tons per day.

The increased efficiency of the furnace could be directed, in the main, to either increased output or to economy of fuel, according to the location of the works and as the commercial problem suggested.

The drying of the blast found, to some extent, its equivalent in an increase of temperature in the hot-blast which was wholly available, as the removal of the moisture represented a calorific gain in the furnace hearth proportionate to the quantity of moisture removed; but the dry-blast provided uniformity, which the hot-blast did not provide.

VISITS AND EXCURSIONS AT THE AMERICAN MEETING.

In connection with the meeting in America an influential General Reception Committee was formed to make the necessary arrangements for the reception and entertainment of the Institute. The President was Mr. John Fritz, Bessemer Medallist and Honorary Member of the Iron and Steel Institute, Past-President of the American Institute of Mining Engineers, and of the American Society of Mechanical Engineers. The following gentlemen acted as Vice-Presidents: Mr. James Gayley, President of the American Institute of Mining Engineers; Mr. A. Swasey, President of the American Society of Mechanical Engineers; Mr. C. Hermany, President of the American Society of Civil Engineers; Mr. B. J. Arnold, Past-President of the American Institute of Electrical Engineers; Mr. W. E. Corey, President of the United States Steel Corporation; Mr. C. Kirchhoff, Past-President of the American Institute of Mining Engineers; and Mr. R. E. Jennings, New York. Other members were Messrs. Theo. Dwight, New York; James A. Burden, New York; G. W. Maynard, New York; S. W. Baldwin, New York; James Douglas, Past-President of the American Institute of Mining Engineers, New York; A. L. Colby, New York; R. Moldenke, New York; William Sellers, Philadelphia; John Birkinbine, President of the Franklin Institute, Philadelphia; Walter Wood, Philadelphia; W. B. Ridgely, Washington; Dr. David T. Day, Washington; Julian Kennedy, Pittsburg; J. M. Camp, Pittsburg; S. T. Wellman, Past-President of the American Society of Mechanical Engineers; A. I. Findley, Cleveland; T. Guildford Smith, Buffalo; F. Howard Mason, Buffalo; Arthur Thacher, St. Louis; Herbert W. Wheeler, St. Louis; R. W. Hunt, Past-President American Institute of Mining Engineers, Past-President American Society of Mechanical Engineers, Chicago; E. C. Potter, Chicago; and T. W. Robinson, Chicago.

The Executive Committee consisted of Mr. Charles Kirchhoff, Chairman; Mr. Robert E. Jennings, Treasurer; and Mr. Theodore Dwight, Honorary Secretary.

In the arrangements made by the Reception Committee nothing was neglected to make the visit an enjoyable one. The details were admirably carried out by the Executive Committee and their staff, who spared no pains to insure the comfort and convenience of the members, and it would be impossible to overestimate the value of the services so ungrudgingly rendered. Indeed, throughout the whole period spent in America the party was unanimous in its appreciation of the unremitting care and attention of which it was the object, while the unfailing courtesy, kindness, and tact displayed by the Honorary Secretary, Mr. Theodore Dwight, endeared him personally to every member present, and contributed in a very high degree to the success of the meeting.

The badge, which was presented to the members by the Reception Committee, took the form of an artistically designed brooch. The members of the various Reception Committees wore the badge with red enamel, while blue indicated members and guests attending. The officers of the Institute wore a badge with white enamel, while that worn by the Executive Committee was distinguished by its pale-blue colour.

During the stay in New York, members were courteously extended the hospitality of the Engineers' Club, of which they had been made honorary members.

The general outlines of the visit, and of the various functions and excursions involved, were embodied in a tasteful programme, which was presented to the members upon their arrival. It contained a short historical note relating to the Iron and Steel Institute; lists of the officers, and of the Executive and General Committees; the local committees for the various towns comprised in the tour, and special notices, designed to facilitate the arrangements for travelling and for the transport of necessary baggage. It also contained brief epitomes of the arrangements made for the entertainment of the visitors in the towns mentioned, and a schedule of the times of starting and arriving of the special trains, which were as follows:—

General Itinerary.

Monday, Oct. 24, to Thursday, Oct. 27	In New York.		
Thursday, Oct. 27	leave New York	10.30 A.M.	via. Penn. R.R.
	arrive Philadelphia	12.30 P.M.	

Bethlehem Steel Co. party leaves New York by Central New Jersey Railway, Liberty Street Ferry, 10 A.M., arrives Bethlehem 12.30 A.M., leaves Bethlehem 3.45 P.M., arrives Philadelphia 5 P.M., *viâ* Philadelphia and Reading Railroad.

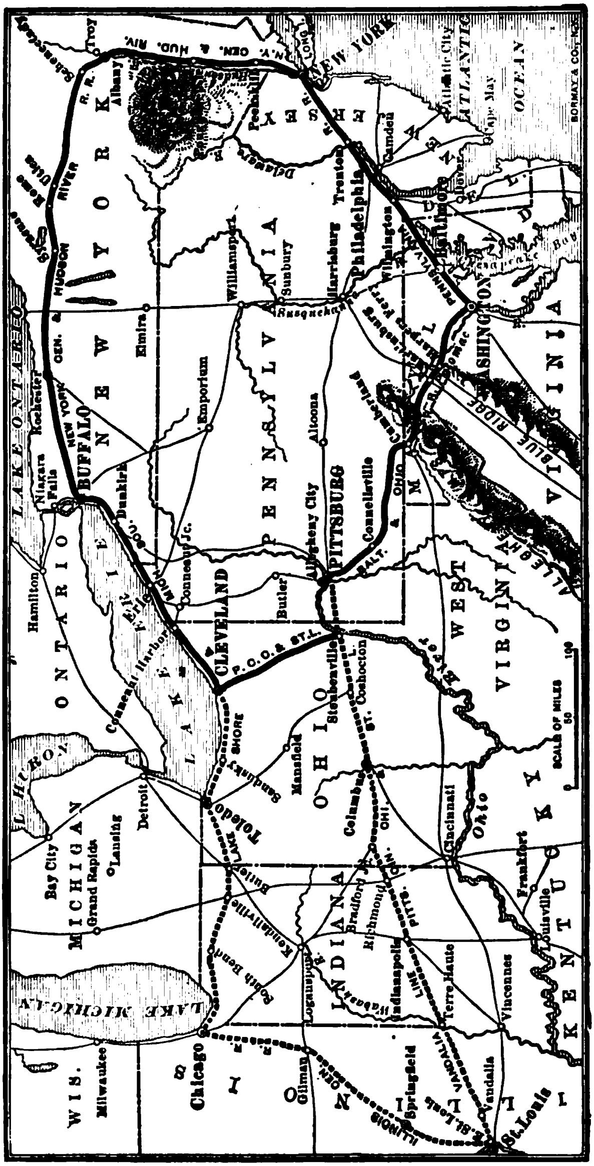
Friday, Oct. 28	in Philadelphia.		
Saturday, ,, 29	leave Philadelphia	8.30 A.M.	
	arrive Washington	12.30 P.M.	
Sunday, ,, 30	in Washington.		
Monday, ,, 31	leave Washington	8.30 A.M.	B. & O. R. R.
	arrive Cumberland	12.30 P.M.	(Luncheon).
	arrive Pittsburg	6.30 P.M.	
Tuesday, Nov. 1 Wednesday, ,, 2	in Pittsburg.		
Thursday, ,, 3	leave Pittsburg	2.0 P.M.	G. & P. R. R.
	arrive Cleveland	5.30 P.M.	
Friday, ,, 4	in Cleveland.		
Saturday, ,, 5	leave Cleveland	1.30 P.M.	Lake Shore
	arrive Conneaut	3.0 P.M.	& M.S.
	leave Conneaut	5.30 P.M.	
	arrive Buffalo	8.30 P.M.	
Sunday, ,, 6 Monday, ,, 7	in Buffalo and Niagara Falls.		
Tuesday, ,, 8	leave Buffalo	8.0 A.M.	N. Y. C. &
	arrive Albany	4.0 P.M.	H. R. R. R.
	arrive New York	8.30 P.M.	
Wednesday ,, 9 Schenectady Party	leave Albany arrive New York	7.0 P.M. 10.30 P.M.	

The details relating to the St. Louis excursion, which started from Pittsburg, were as follows:—

St. Louis Itinerary.

Thursday, Nov. 3	leave Pittsburg	8.10 P.M.	P. C. C. &
Friday, ,, 4	arrive St. Louis	1.42 P.M.	St. L. R. R.
Saturday ,, 5 Sunday, ,, 6	in St. Louis.		
Monday, ,, 7	leave St. Louis	11.50 P.M.	Illinois Central.
Tuesday, ,, 8	arrive Chicago	8.20 A.M.	
Wednesday, ,, 9	leave Chicago	6.0 P.M.	Michigan
Thursday, ,, 10	arrive Niagara Falls	7.30 A.M.	Central.
	leave Niagara Falls	6.0 P.M.	N. Y. C. &
	arrive Buffalo	6.30 P.M.	H. R. R. R.
Friday, ,, 11	leave Buffalo	6.0 P.M.	
Saturday, ,, 12	arrive New York	5.0 A.M.	

In addition to the foregoing information, the general programme also contained a list of the members, visitors and ladies, attending the meeting, or joining the party at various points on the route, which is shown on the accompanying map:—



The thick black line indicates the route of the main excursion, starting from New York, and comprising visits to Philadelphia, Washington, Pittsburg, Cleveland, Buffalo, Schenectady, and back to New York. At Pittsburg the party divided, the St. Louis contingent travelling to St. Louis and Chicago, and thence to Buffalo. On arriving at Buffalo they kept to the route previously traversed a few days earlier by the main party, arriving in New York three days later.

The President, Sir James Kitson, Bart., M.P., Mr. E. Windsor Richards, Mr. E. P. Martin, and Mr. W. Whitwell, and more than a hundred of the members travelled from Europe in the steamship *Celtic*, of the White Star Line. The arrangements for ocean transport were ably carried out by Messrs. Thomas Cook & Sons, who had been officially appointed passenger agents in connection with the American meeting.

VISIT TO NEW YORK.

The Local Reception Committee consisted of the following gentlemen: Mr. James A. Burden, Chairman; Mr. George W. Maynard, Vice-Chairman; Mr. Stephen W. Baldwin, Treasurer; and Dr. Richard Moldenke, Secretary. The other members were Messrs. Lewis W. Francis, Chairman of the Invitation Committee; Charles A. Moore, Chairman of the Reception Committee; E. E. Olcott, Chairman of the Transportation Committee; Thomas Robins, Jr., Chairman of the Entertainment Committee; T. Commerford Martin, Chairman of the Banquet Committee; Henry D. Hibbard, Chairman of the Programme Committee; Henry M. Howe; Benjamin Atha; J. Langeloth; Ferdinand Roebling; H. L. Shippy; Hon. Edward Cooper; Hon. James A. Canda; Warren Delano, Jr.; Cleveland H. Dodge; D. Willis James; W. O. Fayerweather; James Gayley; Hon. E. H. Gary; W. B. Kunhardt; G. F. Kunz; John Hayes Hammond; Peter Cooper Hewitt; Alexander C. Humphreys; Albert R. Ledoux; L. G. Laureau; W. B. Lieb, Jr.; George G. McMurtry; C. A. Moore, Jr.; Moses Taylor Pyne; J. A. Rawlins; W. D. Baldwin; J. B. F. Herreshoff; William H. Nichols; Charles F. Rand; T. A. Rickard; E. G. Spilsbury; John Stanton; H. R. Towne; Hon. W. H. Wiley; David Williams; Frank S. Witherbee; Charles M. Jacobs; and J. Morgan Clements.

A Reception Committee for the entertainment of the ladies accompanying the members was formed consisting of: Mrs. Roswell D. Hitchcock, Chairman; Mrs. James A. Burden; Mrs. Abram S. Hewitt; Mrs. Andrew Carnegie; Miss Kirchhoff; Mrs. Ambrose Monell; Mrs. Albert L. Colby; Mrs. Horace See; Mrs. James Gayley; Mrs. Henry M. Howe; Mrs. Henry D. Hibbard; Mrs. George W. Maynard; Mrs. Louis W. Francis; Mrs. Charles A. Moore; Mrs. George B. Day; Mrs. R. W. Raymond; Mrs. Peter Cooper Hewitt; Mrs. W. D. Baldwin; Mrs. F. R. Hutton; Mrs. Henry S.

Monroe; Mrs. T. Commerford Martin; Miss Van Santvoord; Mrs. Norton B. Otis; Mrs. Thomas Robins, Jr.; Mrs. Henry R. Towne; Mrs. John Thomson; Mrs. David Williams; Miss Maynard; and Miss Olcott.

The bulk of the party, which ultimately consisted of about 250 members and 70 ladies, arrived in New York on the morning of Sunday, October 23, when no less than four steamers simultaneously disembarked their passengers, the ocean voyage having been unduly protracted owing to the unfavourable weather conditions prevailing. The members were met, on landing, by Mr. John Fritz, President of the General Committee, and other members of the Reception Committee. Special facilities were accorded by the Treasury Department at Washington in passing the baggage through the U.S. Customs. Electric automobiles were placed by the Reception Committee at the disposal of those landing, to convey them to their hotels. The headquarters of the Institute were at the new Hotel Astor, at which most of the party had elected to stay during the four days spent in New York. On arriving at the Hotel Astor, the members made their way to the College Room, a large room on the eighth floor, *en suite* with a handsome hall, at the other end of which was situated the large ballroom, in which the meeting of Wednesday, October 26, for the reading and discussion of papers, was held. The College Room was the headquarters of the Institute during the stay in New York, and it was here that registration of the members was effected, and the badges, programmes, and notices were given out. It was also the point of departure for the various excursions, the members assembling in groups, previous to their departure under the charge of students of Columbia University, who kindly acted as guides upon these occasions.

The special programme relating to the New York meeting was compiled by Mr. F. W. Schultz. It took the form of a handsome booklet, profusely illustrated, and containing interesting notes relating to the places to be visited. A guide to New York and a folding map of the city were also presented.

Mr. Geo. W. Maynard, Vice-Chairman of the New York Local Committee, who during the absence, through illness, of Mr. James A. Burden, the Chairman of the New York Committee, had been in charge of the New York arrangements, had provided cards containing information concerning places of divine worship in New York City, and parties were formed to attend the various churches. As a result of the excellent arrangements of the New York Local Committee, and of the untiring efforts of Mr. Theodore Dwight, Honorary Secretary of the Executive Committee, who took special interest in all of the doings of the Local Committee, Monday was an extremely busy day, being taken up entirely by visits and excursions.

On Monday, October 24, through the courtesy of the Interborough Rapid Transit Company, special trains were placed at the disposal of members and their guests, enabling them to inspect the New York Subway. An inspection of the power station of the Interborough Company, the latest addition to the current generating services of Manhattan Island, was then made.

Simultaneously another party visited the plant of the Nichols Chemical Company, Laurel Hill, Long Island. The members were much interested in the smelting, Bessemerising, and electrolytic refining of copper, which they witnessed. The capacity of the refining plant is about 40 tons a day. The party was received by Mr. J. B. Herreshoff, general manager of the works.

In the afternoon the New York Navy Yard and the Waterside station of the New York Edison Company were visited. A steamer courteously tendered by the United States Navy left the pier at East Forty-second Street and East River at 2.30 P.M., and returning from the Navy Yard the steamer proceeded up the East River to the Waterside station of the New York Edison Company, Thirty-eighth Street and East River, arriving about five o'clock, when the station was running under full load, and the members were enabled to witness one of New York's most interesting power stations, since the largest types of reciprocating engines and the steam turbine were seen in operation side by side.

Another party inspected the Hudson Tunnel Works. Through the courtesy of the New York and Jersey Railroad Company and its chief engineer, Mr. Charles M. Jacobs, steamers were in waiting at the pier at West Thirty-fourth Street, North River, at 2 P.M. On the way to the tunnel the steamers stopped at Weehawken, New Jersey, to allow inspection of the New Jersey shaft of the Pennsylvania Railroad tunnels.

Another party also left headquarters at two o'clock, and was met on the New York side of the Brooklyn Bridge by a special car and guides to facilitate the inspection of the interesting features of both the Brooklyn and Williamsburg bridges.

For the benefit of such members as preferred to visit lower New York City and inspect the Park Row Building, Mr. Thomas Robins kindly placed at their disposal the offices of the Robins

Conveying Belt Company, in one of the towers of this building. Several members embraced this opportunity of visiting the tallest building in New York.

Other parties visited the Stevens Institute of Technology at Hoboken, and Columbia University.

On Tuesday, October 25, a trip up the Hudson was made to the United States Military Academy at West Point. The steamer *Monmouth*, one of the fastest vessels on the Atlantic seaboard, had been provided through the courtesy of Mr. E. E. Olcott, Chairman of the Transportation Committee, and the Central Railroad of New Jersey. The New York Committee provided a collation, which was served on board before the arrival at West Point. On the return trip tea was served. A special display of water-throwing was made by the fire-boat *George B. McClellan*. On arriving at West Point Brig.-General A. L. Mills, Superintendent of the United States Military Academy, greeted the party at the dock. Subsequently, Col. Tilman, Col. Learned, Col. West, and other officers welcomed the Institute, and conducted the party through the various buildings, including the Memorial Hall, the Library, the Ordnance Museum, and the Chapel. After a two hours' inspection the return trip was begun at 3.15 P.M., the *Monmouth* reaching her pier at New York before six o'clock. Both on the outgoing and home-coming trips a musical entertainment was furnished by a string band. One feature of novelty was the singing of negro melodies, or coon songs, to the accompaniment of the banjo by three coloured vocalists, who were applauded again and again. Miniature silk flags—the national emblems of Great Britain and the United States—were distributed as souvenirs to the 450 ladies and gentlemen present.

The evening was left open to permit members to attend private social functions. Mr. James A. Burden, Chairman of the New York Reception Committee, entertained the President, Past-Presidents, and the Reception Committee at dinner at the Metropolitan Club. At 10 o'clock, Mr. and Mrs. Carnegie gave a reception at their house in East Ninety-first Street.

During the stay in New York, the ladies of the party were taken on October 26 for automobile drives. The route selected included Riverside Drive and Washington Bridge, *viâ* Fifth Avenue and Central Park. A stop was made for a reception at Columbia University, where the guests were received by Professor Nicholas Murray Butler, and a committee of professors and their wives. In the afternoon tea was served at the St. Regis Hotel, and visits were paid to Messrs. Tiffany & Company's establishment, where a most interesting collection of precious stones was shown by Mr. George F. Kunz; to the Metropolitan Museum of Art, and to the American Museum of Natural History. In the evening there was a theatre party for the ladies at the Broadway Theatre.

THE INTERBOROUGH RAPID TRANSIT COMPANY.

The new Rapid Transit Subway and Power-house, which was opened to the general public on October 27, forms part of a comprehensive scheme for an underground-railway system, which, when completed, will cover 45 miles in New York (Manhattan), with an additional 135 miles beyond the limits of Manhattan Island, and is already beginning to realise its object of diminishing the excessive crowding which takes place on the elevated railways and on the surface-cars during the busiest hours of the day. The project involved tunnelling in solid rock, and entailed underpinning, in order that the safety of the tall buildings on the line of route might not be imperilled. The system begins near the Post Office, in the business part of the city, and continues, so far as the sections visited are concerned, to 104th Street in the residential quarter, a distance of 7 miles, the whole of which is a four-track way, to enable two speeds to be maintained—an ordinary and an express service. The capacity of the trains is 1200, and it is estimated that during the busiest time of the day 72,000 express and 90,000 ordinary passengers per hour can be carried. The power-house will, when fully equipped, have cost £1,400,000, the combined power of the engines on maximum load being 120,000 horse-power. The accepted tenders for the construction of the first four sections of the subway aggregated £21,600,000, with £200,000 additional for contingencies and the purchase of ground rights. The actual plant consists of nine 5000-kilowatts Westinghouse alternators, delivering twenty-five cycle three-phase current at 11,000 volts, at seventy-five revolutions per minute, the driving machinery being nine Allis-Chalmers engines of 7500 indicated horse-power each. The boiler plant consists of sixty Babcock and Wilcox horizontal water-tube boilers, each having 6000 square feet of heating surface, placed on one floor in batteries of two boilers each, and supported on the steel columns of the building. Grates for hand firing are installed for the first thirty-six boilers, and automatic stokers for twelve boilers. Each boiler has 100 square feet of grate area, the fuel used being small anthracite.

HUDSON RIVER TUNNEL-WORKS.

The Hudson River Tunnel-works present many features of great interest. The construction of the tunnel is being carried on, as is usual in operations of this description, by means of compressed air; but all records of a similar nature have been eclipsed by the speed with which the work is being done. Before arriving at the tunnel the visitors were shown the New Jersey shaft of the Pennsylvania Railroad tunnel, a stop being made at Weehawken for this purpose. The tunnel inspected is said to be the largest ever driven for this purpose, being 180 feet long, 100 feet wide, and 80 feet deep. When completed it will be used for the purpose of distributing the electrical motive-power for the operating of the two lines.

NAVY YARD, BROOKLYN.

One of the most interesting visits was that paid to the Navy Yard, Brooklyn. It was at this yard that the United States battleship *Connecticut* had been launched, about a fortnight earlier. This was regarded in the States as a somewhat momentous event, inasmuch as it affords the first instance of a large battleship having been constructed wholly in a United States Government yard. The *Connecticut* is a vessel of 16,000 tons burthen, and had a trial speed, on her first run, of 18 knots.

GENERATING STATION OF THE NEW YORK EDISON COMPANY.

The power-house of the New York Edison Company has the largest electric service of any single corporation in the world, and furnishes current to no less than 32,000 customers on Manhattan Island, and to a number of others living in the neighbourhood. The waterside station building is 272 feet long by 197 feet wide, divided, by a longitudinal wall, into engine and boiler-houses. There are sixteen vertical reciprocating engine and generator units of 8000 horse-power each, arranged in two rows, and fifty-six boilers of 650 horse-power each. The engines are three-cylinder, compound, double-acting, with the high-pressure cylinder between the two low-pressures. When operating with a steam pressure of 180 lbs. at the throttle and 27 inches vacuum at the low-pressure cylinder, they will develop about 5500 horse-power on less than 12½ lbs. of dry steam per indicated horse-power hour, and are capable of developing 10,000 horse-power at maximum cut-off. Some of the principal dimensions are: Cylinder diameters, one at 43·5 inches and two at 75·5 inches; cylinder ratio, 6·02 : 1; crank angles, 101 degrees, 126 degrees, 133 degrees; valves, Poppet high, Corliss low; diameter piston-rods, 9 inches; hollow shaft, 35 feet long, 29⅜ inches maximum diameter; total weight on bearings, 490,000 lbs.; flywheel diameter, 23 feet; weight, 72 tons. There are fifty-six water-tube boilers, placed in two stories of the boiler-house, so that two rows are above two other rows. The coal-bunkers are on a floor above. Each boiler has 6500 feet of heating surface and 110 feet of grate area, and twenty of them are equipped with automatic stokers. The generators are of the revolving field type, having forty poles. When running at seventy-five revolutions per minute they can generate 25-cycle three-phase current at 6600 volts. Their normal rating is 3500 kilowatts each, with 5000 kilowatts for short periods. The capacity of the installation, in terms of electric lighting, is 3,068,041 lamps of 16 candle-power each. An interesting feature of the plant is the turbo-generator group, which was installed experimentally, side by side with the reciprocating engines, to which it had in the first instance been intended to confine the type.

THE EAST RIVER BRIDGES.

The older of the two existing bridges connecting New York and Brooklyn is the far-famed Brooklyn Bridge, which was begun in 1870 and opened in 1883. It is a suspension bridge, consisting of a central span and two land spans, carried from anchorages on either side, over two towers. The channel span is 1595 feet 6 inches; the two land spans 930 feet each, the Manhattan approach 1562 feet 6 inches, and the Brooklyn approach 971 feet, the total length, with extensions, being 6537 feet. The width of the bridge is 85 feet, and the height from water to roadway 119 feet. There are two railway tracks, two car tracks, two roadways for vehicles, and an elevated central foot-walk. The height of the towers is 278 feet above high-water mark; they rest upon caissons varying from 171 feet by 102 feet, on the New York side, to 168 feet by 102 feet, on the

Brooklyn side. The bridge is carried by four cables each $15\frac{3}{4}$ inches in diameter, consisting of 5296 oil-coated and galvanised steel wires laid parallel (not twisted), closely wrapped into a solid cable, by means of galvanised wire. The members were shown over the bridge by Mr. Archibald M'Lane.

The new Williamsburg Bridge, also known as the New East River Bridge, is the largest in the world, and cost nearly £4,000,000. The main span between the towers is 1600 feet, the total length, with approaches, being 7000 feet. The bridge has two levels accommodating two railroad tracks, four trolley tracks, two roadways, two sidewalks, and two bicycle paths, and is 114 feet wide. The two steel towers which carry the cables each weigh 3000 tons, and have a total height of 335 feet above mean high water. There are four main cables, each 18 inches in diameter, 3000 feet long, and weighing 2,500,000 pounds, composed of 7696 $\frac{3}{16}$-inch straight steel wires, and they have an ultimate strength of 50,000,000 pounds and a working strength of 10,000,000 pounds. The system of wires is similar to that adopted on the Brooklyn Bridge cables. The steel work for the approaches and suspended trusses was furnished by the Pennsylvania Steel Company; the New Jersey Steel and Iron Company being the contractors for both towers and shore spans. Members were shown over the bridge by Mr. K. L. Martin.

Two other bridges are under consideration—the Manhattan Bridge, intended to span the East River at a point between the Brooklyn Bridge and the recently completed Williamsburg or New East River Bridge, and the Blackwell's Island Bridge—to connect the Borough of Manhattan between Fifty-ninth and Sixtieth streets with the Borough of Queens, which when finished will be the heaviest and most capacious bridge ever constructed. With the exception of the Forth Bridge, it contains the longest truss span ever built. It will have a double deck, and has been designed for heavy waggon traffic, besides the carrying of six railroad tracks and two promenades.

THE INSTITUTE DINNER.

On Wednesday evening the Institute Dinner was held in the ballroom of the Waldorf-Astoria, with over 350 participants. The guests of the Institute comprised: Mr. John Fritz; Sir Percy Sanderson, K.C.M.G., British Consul-General; Messrs. J. A. Burden,

C. Kirchhoff, H. M. Howe, R. W. Raymond; the President of the American Institute of Mining Engineers; the President of the American Society of Mechanical Engineers; the President of the American Institute of Electrical Engineers; the President of the Franklin Institute; Julian Kennedy (Pittsburg); Guildford Smith (Buffalo); S. T. Wellman (Cleveland); R. W. Hunt (Chicago); G. W Maynard; S. W. Baldwin; L. W. Francis; C. A. Moore; E. E. Olcott; T. Robins, Jr.; Dr. R. Moldenke; Bion J. Arnold; T. C. Martin; Robert A. Franks; Henry D. Whitfield; A. L. Colby; Admiral Melville; Joseph Wharton; Wm. Metcalf; John F. Wallace; C. V. Fornes; W. H. Fletcher; W. E. Corey; Col. Jas. H. Hoyt; Henry D. Hibbard; Admiral Coghlan; General Mills; Dr. K. C. Humphreys; Dr. R. Bell, Director of the Geological Survey of Canada; and Sir Walter Foster, M.P.

Prominent among the decorations were the British and American flags, while intermingled with the flowers were brilliant specimens of autumn foliage. The *menu* was bound in heavy paper covers, with an impressionist picture of an open-topped blast-furnace on the front cover. Inside, an allegorical picture of the progress of America from aboriginal conditions to modern civilisation faced a representation of a partly completed steel-frame sky-scraper, having the various courses of the dinner set forth on the several stories, ascending to the cigars and coffee, and topped with a derrick swinging a beam in place bearing the word "speeches." When the ices were carried in, in procession, representations of numerous great engineering works were borne on the shoulders of the waiters, the models including the celebrated flat-iron building, the skeleton of a tall building, a generator, and a man-of-war. An interesting souvenir was presented to each guest during the dinner in the form of a casket, copied from the silver casket presented to Mr. James Forrest, Secretary of the Institution of Civil Engineers, by American engineers in 1896. The *menus* and caskets were presented to the guests by the Reception Committee at the suggestion of Mr. T. C. Martin, Past-President of the American Institute of Electrical Engineers, to whose organising skill the conspicuous success of the dinner was largely due.

The chair was occupied by the President, who happily proposed a joint toast to the King and to the President of the United States, the rulers of two great kindred countries, both rulers apostles of peace. The toast to the Reception Committees was proposed by Sir James Kitson, Bart., M.P. (Past-President). "We cannot," he said, "forget the many kindnesses which have been bestowed upon English ironmasters by our old friend, John Fritz, the Chairman of the Reception Committee. We also know how much he is indebted to the activity and intelligence of Mr. Kirchhoff, a younger, but perhaps, I may be permitted to say, an equally brilliant man in his own sphere; and to Mr. Theodore Dwight also, who has worked so hard in the preparation for our reception that he is *hors de combat*, and this evening he is taking a rest, which I hope will bring him up to-morrow smiling once more. I think, Mr. Carnegie, you are very fond of records, and perhaps I may claim to break a record, because, as the President of the Iron and Steel Institute fourteen years ago, I had then to return thanks to you for your graceful hospitality, and I venture to say that that is a record, after an interval of fourteen years amid all the worry and trouble of the iron trade in England, seeing our young son rushing away so victoriously in the walks of commerce, while we older people can only drag on timorously and slowly, but still managing to hold our heads above the water. But these meetings are something more than mere meetings of pleasure — they are meetings of instruction. May I recall, when we were welcomed in the Chickering Hall by Mr. Carnegie on your behalf fourteen years ago, he said that all you had and all you knew would be open to our inspection and for our use. That promise you Americans, all of you, faithfully and generously carried out. These meetings make for something more than even pleasure and instruction; they make for the solidarity of the Anglo-Saxon race. I remember there was a moment when there were some dark clouds, owing to some difficulty with an insignificant South American state, and I was overwhelmed with letters from my iron-trade friends who had welcomed me fourteen years ago. They said, 'Take no heed of those little pin-pricks. We mean nothing by them. You may rest assured that peace will be kept between these two great nations.' And those meetings, those friendships, had something to do with it, I hope, because we understood one another, and it would be most inhuman, as Mr. Carnegie said, to settle such paltry differences by anything but arbitration—rather than by the arbitrament of war. We have been a very fortunate Institution. We have been received by the Emperor of Austria, by the King of the Belgians, by the King of Sweden, and by other Princes. Let me say, that nowhere, whether by Emperors, by Kings, or Princes, have we been received so magnificently as we have been received in the Republic of the United States. May I be permitted to recall that in 1890 we had at the end of all these brilliant receptions a send-off dinner given by Mr. Carnegie in his own home, and a great American poet, who would have been a greater poet if he had not been a better steel-maker, Dr. Raymond, composed and read to us a poem which I preserved and carefully kept, and from which, if you will permit me, I will read you one or two verses. Dr. Raymond wrote:—

"What! you are already going away?
Where is that ancient virtue then,
We used to hear so much of, pray,
The staying power of Englishmen?

Your sires and ours were different stuff:
They did not cleave the ocean foam
For one short month, and say 'Enough,'
And set their yearning souls for home.

Well, science has made ocean trips
So trivial that you came with ease;
Now, alas, too many ships
Invite you to recross the seas.

Yet we take comfort since we know,
Whatever else remains unknown,
We cannot lose you now for long;
You sail away—you'll not be gone.

When folks in such a hurry pack,
They make mistakes, and you will find
It is our hearts you carry back,
And yours that have been left behind!

We have carried our American hearts with great difficulty for many years. They are too exciting, too agitating, too large for our bosoms. We come to give them back again. We come to claim our hearts and to give you yours. We come to claim them at a moment of great anxiety, and, I ask you, do you think that these men, who police the seas, who teach all nations the courtesies of the seas—and the naval officer is always a gentleman—I ask you whether you or we will allow irresponsible officers, or fleets, to interfere with the peaceful avocations of humble fishermen, who are gathering from the sea a hard-earned livelihood? Gentlemen, you are very good to us, and I am satisfied that in the hour of need the Anglo-Saxon race will be united to keep open the ocean to the commerce of the world."

The toast of "The Reception Committee" was acknowledged by Mr. CHARLES KIRCHHOFF, Chairman of the American Executive Committee, who alluded to the fact that the American trade, once so small that it was held in the lap of Great Britain, had grown too heavy to be so handled, and now the iron industries of the two countries were properly advancing side by side.

A toast to "The Institute's Guests" was proposed by Mr. E. WINDSOR RICHARDS, Past-President, to which acknowledgments were made by Rear-Admiral COGHLAN, United States Navy, and by Dr. ALEXANDER C. HUMPHREYS, President of the Stevens Institute of Technology.

Mr. E. P. MARTIN, Past-President, proposed a toast to "The American Engineering Societies." These societies were, he noticed, owing to the munificence of Mr. Carnegie, soon to be in possession of a palatial dwelling, fitted in every respect for the work they had to do. He confessed that he felt inclined to break the Tenth Commandment and covet a similar dwelling for the Iron and Steel Institute. The response to this toast was made by Mr. H. M. HOWE, Past-President of the American Institute of Mining Engineers, and Bessemer Gold Medallist. "On behalf of the many American Engineering Societies," he said, "I give you a most hearty welcome. I would like you to have some appreciation of the vastness of this welcome. Every American city of any importance has its Engineering Society or Societies — say in round numbers 500 societies, if not 1000. Each of these societies has many members. Three of those enumerated have collectively 9000 members—the others will doubtless bring this up to 100,000 members. The Iron and Steel Institute has about 1800 members, to each of whom there is a distinct, separate, and hearty welcome from each of the 100,000 of my constituents. So that by easy multiplication we have 180 million welcomes compressed into these few words. In many cases a constituent of mine belongs to two Engineering Societies. Such a one, in that he thus presents two distinct aspects in spite of having the same chemical composition, is clearly allotropic as distinguished from the common orthotropic or one-Society man. There are others again of whom each belongs to several Societies, and thus appears polymorphously; still others belong at once to your august body and to the vast horde of my constituents; so that, as American engineers subjectively, they welcome themselves objectively as members of the Iron and Steel Institute; the welcome is of the subjective-objective type. Accept, Mr. President and gentlemen, these 180 million heartfelt and hearty welcomes, orthotropic, allotropic, polymorphous, and subjective-objective.

"We are proud to welcome you as representatives of that guild which boasts such names as Watt and Stephenson, as Bessemer, Siemens, Bell, and Thomas, as Nasmyth and Cort. While we are not wholly unmindful of our own inventive powers, and while we have not been slow to adopt your inventions, and to develop them on a very grand scale, yet we remember that we owe to you and your predecessors, the older British metallurgists, almost every invention of the first rank in the metallurgy of iron and steel. We owe to you every important process by which wrought iron and steel are now made, the puddling process, the Bessemer and open-hearth processes, both acid and basic, the crucible steel process, and the pig washing process, to say nothing of many inventions of immeasurable value, such as the hot-blast, grooved rolls, and the steam-hammer.

"We are proud to welcome you not only as the representatives of the great British iron industry, but of these illustrious inventors; we are prouder still to feel that though 'seas between us braid hae roar'd,' by blood and birth we are your, and their, brothers.

"Where can history show so resplendent a mother and daughter as Britannia and Columbia, the greatest powers of to-day, one a majestic Juno, the other a heroic Brunhilde? Their great work is to perfect their common type of civilisation, based on the home, on good faith and fair-play. These Transatlantic excursions are of great value to mankind, in that they make for the ascendency of that civilisation by helping us, their children, to understand each other; for understanding is a long step towards affection, and affection a long step towards efficient co-operation."

The last toast, "The Iron and Steel Institute, and its President," was proposed by Dr. Rossiter W. Raymond in the following words:—

"In the discharge of the honourable duty assigned to me on this occasion, I am both stimulated and embarrassed by the circumstance that I have recently received one of the highest distinctions to which one of my profession could aspire, namely, an election as Honorary Member of the Iron and Steel Institute. The addition of my name to a small list, headed by that of the King of England—may God bless him, as God blessed his sainted mother, to be a potent factor in the peace and progress of the world!—and comprising those of some of the greatest leaders in what is, perhaps, the most important department of scientific and industrial advance affecting the welfare of mankind, might well be supposed to warp my judgment concerning the illustrious companionship to which I have thus been admitted. Permit me, nevertheless, to speak to-night from that standpoint of a disinterested observer, which I have until lately occupied, and which, I fancy, I can still, through force of habit, resume.

"The Iron and Steel Institute was organised in 1869. Thirty-five years is a small period to compass such a career and to deserve and win such world-wide recognition as this Society has achieved. At the inaugural meeting, held in London, June 23, 1869, its first President, the Duke of Devonshire, whose intelligent interest and responsible participation in the British iron manufacture, no less than his official connection with the ancient University of Cambridge, reflected new lustre upon his ancestral rank, delivered an admirable address, sketching the history of the manufacture of iron, noting the steps of its progress, and indicating its situation throughout the world.

"That address illustrates the manner in which great scientific improvements produce their revolutionary results. Not at the date of the invention of the steam-engine, the puddling-furnace, the rolling-mill, the Bessemer converter, the open-hearth furnace, the railroad or the telegraph, did either of these exhibit its full effect upon the world. At a later period, when improved furnaces and mills had combined to make machinery good and cheap and common; when railroads had enmeshed all civilised states, and steel rails had brought together producers and consumers; when ocean cables, not one or two, but a hundred, and ocean steamers by the thousand, had superseded the cumbrous commercial systems of two hemispheres; when swift intercommunication and free trade in ideas had made each forward step of improvement the immediate property of all the world, then it was that the combined effect of all these agencies became evident, with a suddenness and power which puzzled the political economist, worried the statesman, and temporarily disarranged, while it speedily reconstructed in new power, the industries of men. Sir Samuel Baker found the fertilising flood of the Nile to be the result of a thousand small freshets in the mountains of Abyssinia, the confluence of which filled the channels of a hundred creeks, which in turn flooded the tributaries of the Atbara, until at last, far from the sources which had fed its waters, the Blue Nile came down, in a wall of water twelve feet high, to cover and to fructify for a thousand miles the land of Egypt. So new knowledge is distilled from heaven into a thousand souls; so they combine to fill and overflow the ancient channels of human intercourse; so they constitute at last the deluge, out of which emerges a new world. 'After us, the deluge!' is the cry of reckless selfishness; 'After the deluge, *We!*' is man's eternal word of victory, over which God places the rainbow!

"Now, the beginnings of such a beneficent cataclysm fell very near the year 1869. The address of the Duke of Devonshire recognises as already in use, and likely to become widely important, the large blast-furnace, the brick stove for heating the blast, the Bessemer converter, the open-hearth steel-process, the general substitution of rolls for hammers, Whitworth's casting of steel under compression, together with some other inventions, which afterwards more or less disappointed the expectations then entertained concerning them. Moreover, with singular acuteness, it calls attention to the unfavourable effect of the relatively low density and high humidity of the air blown into the blast-furnace during warm weather—an evil which, by a happy coincidence, is to receive its latest discussion and its first effective remedy through the paper of Mr. Gayley at this meeting of the Institute.

"But neither the Duke of Devonshire nor any one else realised the extent of the flood which was to come from the springs he noted. At the time of his address, the world's production of pig iron was, in round numbers, 12,000,000 tons, of which Great Britain produced something less than half; the United States, Germany, and France about one-eighth each; and the rest of the world the remainder, a little more than one-eighth. Last year, the world produced nearly 47,000,000 tons of pig iron, of which Great Britain, though she had increased her output 63 per cent., furnished not quite one-fifth, while the United States, with an increase of more than 900 per cent., contributed much more than one-third, and Germany something more than one-fifth, an increase of 613 per cent. Now, it was in Great Britain that most of the factors of this progress originated, and it is evident that the grand result, like the rise of the Nile, has been exhibited far from its original sources.

"I have said that no one realised in 1869 the extent of this coming flood. But justice requires that I should call attention to the remarkable prescience shown a little later by Abram S. Hewitt, whom the Institute honoured in 1890 with the Bessemer medal. In an address of welcome to the American Institute of Mining Engineers, delivered in this city in May 1872,* Mr. Hewitt prophesied that in 1890 the world's product of pig iron would be 28,000,000 tons — it was 27,630,000 tons; that it would be at the beginning of the twentieth century more than 40,000,000 tons—it was 40,499,786 tons; that the product of the United States in 1897 would be 10,000,000 tons—it was 9,652,680 tons; and that the annual product of this country at the beginning of the twentieth century would be 15,000,000 tons. In this last estimate, made for a period twenty-eight years distant, the prophecy failed. We did not produce, at the time named, 15,000,000 tons per annum, as Mr. Hewitt boldly foretold—our actual product was only 14,960,000 tons!

"I venture to say that our theological friends, if they could produce such a verification of the declarations of an Old Testament prophet, would deem it conclusive proof of Divine inspiration. To me it is a proof that, even outside of the Biblical list, the Divine power, through the operation of the laws it has ordained, may grant to a pure, lofty, disinterested and reverently and profoundly inquiring spirit the ability to read the future!

"Far be it from me to boast of the extraordinary progress of my country in this field. In the first place, that progress has been chiefly based upon virgin resources, for the possession of which we can claim no credit. It was totally without knowledge of the future value of the Lake Superior iron ore deposits that the boundary line between us and Canada was so drawn as to give us almost all of those deposits, upon which our vast iron industry now so largely depends. In the second place, if I were inclined to boast, I should be checked by the reflection that one of the chief agents in the extraordinary development of the American iron and steel business has been that cosmopolitan captain of industry, now president of the Iron and Steel Institute, Mr. Andrew Carnegie, whose merits and achievements have just been recognised by the conferment of the Bessemer Gold Medal, to my mind one of the greatest distinctions which human hands can place upon a human breast.

"In 1888, before your last visit to this country, Mr. Carnegie was already an honoured Member of our Institute. Indeed, in anticipation of that visit, I was delegated to ask him to accept a hearty

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* See the full report of this address in the New York *Engineering and Mining Journal* of May 28, 1872, and its verbatim reproduction in the *Transactions of the American Institute of Mining Engineers*, vol. xxxiv. pp. 200-203.

nomination as President of our Institute. On that occasion, he told me he did not consider himself worthy of such a position; and, though we did not agree with him, we had to submit to his decision! Mr. Carnegie has since accepted the presidency of another society. Whether that signifies that he has lost modesty or gained knowledge in the interim, I will not venture to decide. But this much is certain: if he is good enough for the Iron and Steel Institute, he is good enough for us! And what he has recently done for the engineers of America, in his munificent gift of the Carnegie engineering building, is sufficient proof that we have not lost him, though you may have gained him! We regard him as the best kind of an American—namely, an American by personal choice, rather than by the involuntary accident of birth; and we deem his election as your President a declaration that the labours and rewards of the Iron and Steel Institute are not limited by political boundaries.

"And, finally, I must bear witness, for every one of the students and practitioners who have contributed during the last thirty-five years to the development of the iron and steel industry of the United States, that they have always looked to the Iron and Steel Institute for sympathetic and helpful criticism, guidance, and inspiration. Whatever success we have achieved may justly be added as a jewel to the crown of fame which your Society has fairly earned and may proudly wear.

"In that priceless Volume I. of the *Journal* which I have cited, the first technical contribution is a paper by Isaac Lowthian Bell 'On the Development of Heat and its Appropriation in Blast-Furnaces of Different Dimensions.' I need not say what a profound effect that paper, with its successors, produced upon the metallurgists of the world. To this day no man is competent to write upon the interior reactions of the iron blast-furnace who has not first mastered the classic discussion of that subject by Sir Lowthian Bell. Not only to me as an ardent and grateful personal friend, but also to every one of you, it must be cause for gratitude that this far-seeing, undaunted, wise, and generous pioneer and teacher is still preserved to us, in mental powers unimpaired by age, as it is cause for regret that we cannot see once more among us, as so often heretofore, his benign and noble face.

"But I cannot inflict upon you at this time a detailed account of the varied and effective labours of this Society. I might fairly apply to it, in substance, the famous epitaph of Johnson upon Goldsmith (only no *epitaph* would be appropriate to a career still so vigorous and fruitful), and say that there is no subject of importance to the sciences and art connected with iron and steel which the Institute has not treated, and that it has treated nothing which it has not adorned. In every step of that progress, the fruits of which we enjoy, it has taken an influential part. It is not the Iron and Steel Institute 'of Great Britain': it is the Iron and Steel Institute, representing us all!

"Gentlemen, I offer the toast of 'The Iron and Steel Institute,' and I couple with this sentiment the name of Mr. Andrew Carnegie, its honoured President."

The toast was eloquently acknowledged by the President, who began his remarks by asking all present to join in a silent toast to the memory of Abram S. Hewitt. He then, on behalf of the members present, gave instructions that a cable should be sent to Sir Lowthian Bell, Bart., Past-President, conveying cordial greetings. Lastly, he referred to the obligation the Institute was under to Mr. T. C. Martin for the labours resulting in the banquet. The speeches concluded at about midnight, and the company dispersed to the strains of "Auld Lang Syne."

VISIT TO BETHLEHEM.

On the morning of October 27 a party of members, numbering eighty-eight, left New York (Liberty Street Ferry), and crossed over to the Central Railroad terminus, New Jersey, where they entered the special cars provided, and were taken along the interesting Lehigh Valley route to South Bethlehem. The train was met at a few minutes past twelve on the hill east of the works, and subsequently hauled by one of the works locomotives. The gentlemen who received the party were Mr. C. M. Schwab, Mr. E. M. M'Ilvain (President), Mr. A. E. Borie (Vice-president), Mr. H. S. Snyder (Secretary and Treasurer), Mr. A. Johnston (General Superintendent), and Messrs. A. Halliday and E. O'C. Acker (Assistant General Superintendents), together with twenty-nine other gentlemen in charge of various departments. On arrival at the offices luncheon was served, and souvenirs in the form of handsome gun-metal match-boxes were distributed. After luncheon a train of flat cars was brought up, and the members and their guides were hauled round the works on a tour of inspection, being first shown the forging of a 7-inch gun-tube destined for the United States Navy, and that of a bridge-pin for the new bridge at Quebec. The ingot employed in the first of these two operations weighed 2½ tons, and was in the form of a 42-inch round, while for the second a 30-inch round ingot weighing 1½ ton was used. The cars were then taken into the open-hearth melting-shop, where the members witnessed fluid compression exercised on a 2-ton round ingot, the pressure applied being equal to 6130 lbs. per square inch. They also saw the casting of an armour-plate ingot weighing 56 tons. The party then left the cars and walked through the No. 2 machine-shop, where they saw segments for the Pennsylvania tunnel-works in course of completion, and rejoined the cars at the farther end. Thence they were taken into the hammer-shop, where they were shown the forging of a 45-ton Krupp ingot into plates for testing projectiles. The plates, of which two are ultimately obtained from each ingot, measure when finished 8 feet by 6 feet by 1 foot, and weigh over 10 tons apiece. The bending of gun-shields 4½ inches thick, 84¾ inches wide, and 11 feet long, weighing over 4 tons, was also shown. The visitors again left the cars and walked through the No. 3 machine-shop, where the finishing of armour-plates was witnessed, finally reaching their own train at the west end. They left the works shortly before 4 P.M., and travelled on to Philadelphia to rejoin the main party.

The Bethlehem Works have four 70-foot blast-furnaces with 16-foot boshes, and 10-foot hearths, with a total annual capacity of 200,000 tons. The blast is delivered at 20 lbs. pressure. There is a pig-casting table capable of making 1000 tons daily. The smelting department consists of eleven open-hearth furnaces ranging from 10 to 50 tons. The annual capacity is 100,000 tons of acid ingots and 90,000 tons of basic. There are three hydraulic forging presses of 2000, 5000, and 14,000 tons pressure respectively. The total annual capacity of the armour-plate department is 8000 tons.

VISIT TO PHILADELPHIA.

The Philadelphia Executive Committee was composed of the following gentlemen: Messrs. William Sellers, Walter Wood, H. H. Campbell, James M. Dodge, Alfred J. Major, A. J. Moxham, Leonard Peckitt, John Birkinbine, Edwin S. Cramp, Stanley G. Flagg, Jr., De Courcy May, Frank C. Roberts, and W. R. Webster. Mr. Joseph Wharton was Chairman of the General Reception Committee.

The other members were as follows: Messrs. H. C. Adams, J. B. Bonner, E. P. Borden, Cyrus Borgner, George Brooke, George Brooke, Jr., Robert E. Brooke, James C. Brooks, William Burnham, F. von A. Cabeen, James Christie, Dr. Walton Clark, B. Dawson Coleman, J. W. Cochran, Edgar S. Cook, Edw. B. Cook, Alexander B. Coxe, Theron I. Crane, George C. Davis, Thomas Devlin, J. K. Dimmick, C. M. Dodson, T. M. Dodson, Thomas Dolan, Dr. Thomas M. Drown, Theo. N. Ely, H. O. Evans, Howard Evans, B. F. Fackenthal, Jr., E. C. Felton, Frank Firmstone, Dr. Persifor Frazer, John Fritz, F. Lynwood Garrison, J. R. Gilkyson, Chas. F. Godshall, Henry S. Grove, W. J. Hagman, H. L. Haldeman, Joseph Hartshorne, William S. Harvey, James M. Hibbs, E. Hill, H. B. Hirsh, Clement R. Hoopes, S. Howard-Smith, A. F. Huston, C. L. Huston, Alba B. Johnson, John H. Landis, Ernest Law, L. R. Lemoine, E. C. Lewis, Lewis Lillie,. Jawood Lukens, Lewis N. Lukens, Dr. James MacAllister, Charles Major, Edgar S. Marburg, Charles A. Matcham, De Courcy May, Edmund H. McCullough, Andrew S. McGrath, Louis J. McGrath, Captain T. C. McLean, U.S.N., John B. Miles, Theo. H. Morris, William H. Morris, L. T. Nagle, George Ormrod, A. E. Outerbridge, Jr., W. W. Pharo, W. S. Pilling, Lewis A. Riley, Frank Samuel, G. T. Schnatz, H. J. Seaman, John Sellers, Arthur W. Sheafer, W. Lesley Sheafer, Franklin L. Sheppard, Harrison Souder, H. W. Spangler, William C. Sproul, D. G. Stokes, James M. Swank, Edwin Thomas, Samuel Thomas, F. W. Tunnell, S. M. Vauclain, Theodore Voorhees, J. Price Wetherill, Jones Wister, Alan Wood, J. S. Worth, W. G. Worth, and C. H. Zehnder.

The Ladies' Committee comprised:—Mrs. John Birkinbine, Mrs. Francis B. Bracken, Mrs. Cyrus Borgner, Miss Birkinbine, Mrs. Edgar S. Cook, Mrs. Theron I. Crane, Mrs. F. von A. Cabeen, Mrs. S. H. Chauvent, Mrs. Richard Day, Mrs. James M. Dodge, Miss Eglin, Mrs. B. F. Fackenthal, Jr., Mrs. Stanley G. Flagg, Jr., Mrs. John W. Fuller, Jr., Mrs. E. C. Felton, Mrs. Irwin Graves, Mrs. S. Howard-Smith, Mrs. Alba B. Johnson, Mrs. Jawood Lukens, Mrs. J. B. McCall, Mrs. G. H. Mumford, Miss Anna P. Newhall, Miss Lucy P. Newhall, Mrs. Leonard Peckitt, Mrs. Wilfred Powell, Mrs. F. C. Roberts, Mrs. H. W. Spangler, Mrs. Wm. J. Turner, Miss A. Roberta Tarr, Mrs. Frank Tenney, Mrs. Wm. R. Webster, Miss Julia Wood, Mrs. Thos. Whitaker, and Mrs. C. H. Zehnder.

Programmes of the visits and excursions, enclosed in a tastefully designed cover, were distributed among the members on arrival.

The Bethlehem party joined the section which had proceeded direct to Philadelphia at the house of the Germantown Cricket Club at Manheim, where, by invitation of the Philadelphia Reception Committee, a charming banquet was served, to which over 300 persons sat down. The party which came direct to Philadelphia from New York, and included the ladies, arrived at the club about 4.30 P.M., after a most interesting drive through the city to Fairmount Park, River Drive, Wissahickon, and Valley Green, and tea was served immediately upon their arrival.

On Friday morning the various Reception Committees of the Philadelphia General Committee assembled at the Bellevue-Stratford Hotel, which served as headquarters, and the entire party was escorted to the Public Buildings, where Mr. Wharton presented the members to the Mayor of Philadelphia, Mr. John Weaver, who welcomed them to the city. Sir James Kitson, Bart., M.P., Past-President, replied on behalf of the Institute.

After this reception the members divided into various parties, and, taking conveyances provided by the Committee, proceeded in various directions to visit the several points of interest which they had selected.

One excursion was to museums, educational and scientific institutions, including the Franklin Institute, the American Philosophical Society, the Historical Society of Pennsylvania, the Drexel Institute, the University of Pennsylvania, the Philadelphia Commercial Museum, and the Archæological Museum. At one o'clock luncheon was served in the Houston Club of the University of Pennsylvania. An excursion which was very largely attended included visits to the shipyards of William Cramp & Sons' Ship and Engine Building Company, the New York Shipbuilding Company, the United States Navy Yard at League Island, and the Otto Hoffmann Coke plant of the Public Service Corporation at Camden, New Jersey. The steamer left Chestnut Street wharf at 10.30 A.M., and proceeded to the Cramp yard. Besides the machine and boiler shops, the principal feature of interest was the cruiser *Colorado*, which had just been completed.

Luncheon was served on the boat *en route* to the League Island Navy Yard, the next stop. Here the visitors spent most of their time inspecting the naval vessels stationed at the yard. The next point visited was the yards of the New York Shipbuilding Company, at Camden, New Jersey. This plant is on the Delaware River, opposite Philadelphia. The final stop was made at the Otto Hoffmann plant.

Other plants thrown open to inspection included the Baldwin Locomotive Works; the works of Messrs. Wm. Cramp & Sons; the New York Shipbuilding Company, Camden, New Jersey; the Lukens Iron and Steel Company, Coatsville; the Link-Belt Engineering Company, Nicetown; the Warwick Iron and Steel Company, Pottstown; the Betts Machine Company, Wilmington, Del.; Southwark Foundry and Machine Company, Philadelphia; Seaboard Steel Casting Company, Chester, Pa.; Bement-Miles Works, Philadelphia; Public Service Corporation of New Jersey; Camden Coke Company, Camden, New Jersey; R. D. Wood & Company, Camden, New Jersey; Isaac A. Sheppard & Company, Philadelphia; Central Iron and Steel Company, Harrisburg, Pa.; Solid Steel Casting Company, Chester; William Sellers & Company, Philadelphia; Penn Steel Casting and Machine Company, Chester; Hilles & Jones Company, Wilmington, Del.; J. W. Paxson & Company, Philadelphia; Belmont Iron Works, Philadelphia; Pencoyd Iron Works, Pencoyd, Pa.; the Phœnix Iron Company, Phœnixville; the Phœnix Bridge Company, Phœnixville; Alan Wood Iron and Steel Company, Conshohocken, Pa.; Welsbach Company, Gloucester, New Jersey; Ferracute Machine Company, Bridgeton, New Jersey; the Pusey & Jones Company, Wilmington, Del.; Cyrus Borgner Company, Philadelphia.

In the evening a reception was held in the Academy of Fine Arts. Mr. Joseph Wharton and Mr. William Sellers, with Mr. Carnegie and Sir James Kitson, received the visitors.

The governing bodies of the Union League of Philadelphia, the Manufacturers' Club, the Engineers' Club, and the Germantown Cricket Club, courteously extended the privilege of honorary membership to the members during the period of their visit.

Cramp's Shipbuilding and Engineering Works.

This is one of the oldest shipyards upon the river, having been founded in 1830; it covers an area of 52·4 acres, and has a river front of 2000 feet. There are eight building slips, which are well equipped with pneumatic and hydraulic machinery. The warships under construction consisted of the battleships *Idaho* and *Mississippi*, and the armoured cruisers *Pennsylvania*, *Tennessee*, and *Colorado*. Up to the present time there have been constructed by this company over 325 vessels and 220 marine engines. The yard has a pay-roll of 14,000 dollars daily. The firm was started by William Cramp in the year 1830, the founder being then only twenty years old, and was, naturally, for the construction of wooden sailing-vessels. It is worth mentioning, as giving an idea of the difference between the undertakings of those days and of the present time, that a single item of plant in the present shop would cost considerably more than the entire establishment of William Cramp sixty years ago; this, indeed, is a notable tool, being the great floating derrick Atlas, the cost of which was 30,000 dollars. It has a capacity of 25 tons, and will hoist 50 feet.

The present company was incorporated by an Act of the United States Legislature in 1872; seven years later William Cramp died, and was succeeded by his eldest son, Chas. H. Cramp, as president of the company. The most important work done here has been in connection with the reconstruction of the American Navy, the first vessel taken in hand being the double-turreted monitor *Terror*. The principal structures comprise the shipyard shops, a building 1200 feet long and of an average width of 72 feet, the total ground and floor area being 460,000 square feet. This is one of the largest structures in the world under one roof. It includes a bending-shed, blackboard-shed, ship-shed, pipe-cutting shop, sheet-iron shop, and joiners' shop; on the ground floor there are two extensive mould lofts, a channel shop on the second floor, a pattern shop on the third floor; a machine-tool department and tool store-house carry the building to four floors. The boiler shop is 384 feet long by 58 feet wide; a new machine shop which has been constructed is 333 feet long by 142 feet wide, and extends to three floors for part of its area. This building is well equipped with modern machine-tools, all driven by electric motors. What is known as the Morris machine shop and foundry has two floors, the combined area being 1226 square feet. The blacksmiths' shop is 307 feet long and 100 feet wide. There are the other usual buildings and departments necessary for works of this character. In the boiler shop are two electric travelling cranes of 50 tons each, one of 20 tons, and also one 5-ton crane. In the Morris machine shop there are two 30-ton and one 20-ton crane. All of these are electric cranes, excepting two in the Morris machine shop. The wet-docks cover a large area, the total length of wharfage available being 5200 feet. Of the eight building slips, four have a building length of 480 feet, two of 500 feet, and two of 600 feet. Six of these slips are provided with overhead gantry and travelling cranes; one of these gantries has a total length of 541 feet, one 629 feet, and another

752 feet. Two of the cranes have a spread of 190 feet and 86 feet hoist; the other has a spread of 176 feet and 73 feet hoist; they are all built of steel. A dry-dock is 472 feet long by 72 feet wide, and has a draught of 22 feet on the sill at mean high water. There are also the machine shops and appliances necessary for repairs. During the past four or five years the mechanical appliances in this shipyard have been completely reconstructed. Nearly all the rivet work is now done by hydraulic riveting, used in the boiler-making, or pneumatic riveting, used in the construction of ships' hulls. For the latter purpose there is a complete system of piping underground, with attachments for flexible hose. In addition to riveting, drilling, chipping, caulking, and the blowing of rivet fires are done by means of this system. It was stated that the total increase of actual value of the shipyard by the enlargements and improvements that had been made since 1875 amounted to £1,000,000. When William Cramp began business he had less than 100 men in his employment; at the present time about 8000 men are employed, and 84,000 dollars have been paid in a week for labour.

The armoured cruiser *Colorado*, which has just been completed, is 502 feet long by 70 feet wide and 24 feet draught, the displacement being 13,765 tons. The engines have cylinders 38½ inches, 63½ inches, and two of 74 inches in diameter, with a 48-inch stroke. There are thirty-two modified Niclausse boilers, with 1632 square feet of grate, fitted with Cramp's shaking-grates. The maximum horse-power developed was 28,000 (main engines); the indicated horse-power per square foot of grate was 17·15 (main engines); and the indicated horse-power per square foot of grate was 18 for the total. The air pressure was 1½ inch. The average speed over four hours' steaming was 22·26 knots. Other particulars are as follows:—

		Port.	Starboard.
Average revolutions per minute		127·59	127·09
Steam pressure	lb.	273	275·5
High-pressure receiver	,,	249·7	249·5
Middle-pressure receiver	,,	99·7	102
Low-pressure receiver	,,	21·4	24·19
Vacuum	in.	21·7	21·4
Throttle, distance open		00·252	00·249
Cut-off, high pressure		00·778	Full gear
,, middle pressure		00·750	,,
, low pressure		00·752	,,

THE LEAGUE ISLAND NAVY YARD.

The League Island Navy Yard covers an area of about 1000 acres, and was founded in 1868, the city of Philadelphia ceding the land to the United States Government in consideration of the sum of one dollar. The League Island Yard forms a safe fresh-water harbour, having a frontage of about nine miles. It is well situated, being in close proximity to supplies of coal and iron, whilst there is a large manufacturing population to draw from. The vessels at the Navy Yard at the time of the visit were the coast-defence monitor *Florida*, the cruiser *Denver*, and the battleships *Alabama* and *Massachusetts*. Members devoted their time principally to the examination of these vessels. In the back-channel was to be seen one of the original monitors of the Civil War.

THE NEW YORK SHIPBUILDING COMPANY.

The works of the New York Shipbuilding Company were founded a little over five years ago. The property comprises 150 acres, and has a water frontage of 4200 feet. The buildings are extensive, covering as area of about 20 acres. There are facilities for constructing vessels up to 1000 feet in length. There are thirty-five electric cranes of various powers, special attention having been paid to the orderly handling of material during the construction of the vessels and machinery. Compressed-air tools are used in all departments, and there is an extensive equipment of hydraulic machinery in the boiler departments of the shipbuilding yard. The punching and bending of plates is done by hydraulic machines. Light and power are supplied from a central station. The first vessel was laid down in the year 1900; since that time twenty-four ships have been launched, amounting to an aggregate of 77,504 tons. At the time of the visit of members there were under construction the United States cruiser *Washington*, 502 feet long, and the battleship *Kansas*, 450 feet long, as well as five light-vessels for the United States lighthouse establishment. The normal working force of this company is about 6000 men.

THE CAMDEN COKE COMPANY'S WORKS.

The coke-ovens and by-product plant owned by the Cambrian Coke Company are controlled by the Public Service Corporation of New Jersey. The plant consists of two batteries, each of fifty ovens, of the Otto-Hoffmann type. The gas produced is used in Camden, and is also pumped to Trenton, through a 12-inch wrought-iron pipe, the distance being 38 miles. Intermediate towns are also supplied from the high-pressure main through regulating-governors, this being the main source of supply of gas for this part of West Jersey. The plant has a capacity for carbonising 500 tons of coal per day; eighty ovens are discharged every twenty-four hours, the average time consumed in the process of carbonisation being thirty hours. The daily production of coke is 350 tons, of which 40 per cent. is used for metallurgical purposes; the remainder is crushed into convenient sizes for domestic use. About fifty tons of what is known as the nut size are packed into paper bags, which contain about half a bushel. The other by-products are tar and ammonia. The average yield per ton of coal is about 1600 lbs. of coke and 3500 cubic feet of 18-candle-power illuminating gas, 5¼ lbs. of pure ammonia, and 10 gallons of tar.

BALDWIN LOCOMOTIVE WORKS.

On October 28 a number of members visited these works. The visitors, after being received by three of the managers, Messrs. Geo. Burnham, Sam. M. Vauclain, and Alba B. Johnson, and entertained to luncheon, were taken round by the departmental heads in small parties, and shown the general offices and drawing offices, the latter of which attracted very general interest owing to the admirable system of filing carried out there. Afterwards they visited the riveting shop, and then proceeded along a portion of the first floor devoted to boiler-flanging. The shops in which the cranks and connecting-rods are planed and finished were likewise objects of great interest to the party, who were taken thence through the foundries and into the power-house, and ultimately to the erecting shops on the ground floor. The annual capacity of the Baldwin Locomotive works at present is 2000 locomotives. The greatest output was reached in 1903, when 2022 locomotives were built, exclusive of repairs to existing locomotives. The number of men employed in these works is 15,800, and the available horse-power developed is 11,334. The acreage comprised in the works amounts to 17. From the establishment of the works to the present time 24,000 locomotives have been built.

THE PENCOYD IRON WORKS.

These works are situated in Montgomery County, opposite Manayunk. The steel department contains one 75-ton and ten

30-ton open-hearth furnaces, their annual capacity being 230,000 tons of ingots. The annual capacity of the works is 200,000 tons of finished products, channel bars, beams, tees, angles, flats, rounds, bars, and bridge steel.

WORTH BROTHERS COMPANY.

A small party, including Mr. E. P. Martin, Mr. A. Lamberton, and a dozen other members, on October 28 visited the rolling-mills and steelworks of Worth Brothers Company at Coatesville. The chief object of interest was the three-high plate mill which was built in 1903, and began rolling plates in August of that year. It has 42-inch by 152-inch rolls, and rolls plates direct from the ingot. Plate-straightening machines are attached to the trains of rolls. The works are also equipped with two 154-inch, two 132-inch, and one 102-inch hydraulic plate shears, with one 110-inch steam shears, with a complete flanging and dishing plant, with a modern machine shop, and with an electric plant. The total annual capacity of the two rolling-mills and steelworks of the company comprises 230,000 tons of ingots, and 245,000 tons of plates, skelp, and sheets.

MARYLAND STEEL COMPANY.

On October 29 a party of members visited the works of the Maryland Steel Company at Sparrows Point. The party was received by Mr. F. W. Wood, president of the company, and by Mr. H. F. Martin, the general manager, who kindly provided special trains. The works have four blast-furnaces, each 85 feet in height, and each equipped with four Whitwell stoves. The total annual capacity is 400,000 tons of Bessemer pig iron and spiegeleisen. The molten metal is conveyed from the furnaces to three 18-ton Bessemer converters, the total annual capacity being 500,000 tons of ingots and 400,000 tons of billets and rails. The company also has 200 Otto-Hoffmann coke-ovens.

VISIT TO WASHINGTON.

The Honorary Local Reception Committee, of which the Hon. William Barret Ridgely was Chairman, and Dr. David T. Day, Secretary, consisted, in addition, of the following gentlemen: The Hon. Paul Morton, Secretary of the Navy; The Hon. V. H. Metcalf, Secretary of Commerce and Labour; The Hon. E. A. Hitchcock, Secretary of the Interior; General A. R. Chaffee; Admiral George Dewey; General Geo. L. Gillespie; General William Crozier, Chief of Ordnance, U.S.A.; Admiral C. M. Chester, Superintendent of the Naval Observatory; Admiral F. J. Higginson, Commandant of the Navy Yard; Admiral G. A. Converse, Chief of the Bureau of Navigation, U.S.N.; Admiral C. W. Ray, Chief of the Bureau of Steam Engineering; Dr. Daniel C. Gilman, President of the Carnegie Institution; Dr. Charles D. Walcott, Director of the Geological Survey; Dr. Otto H. Tittmann, Superintendent of the Coast and Geodetic Survey; Dr. William T. Harris, Commissioner of Education; Dr. Charles W. Richardson, President of the Medical Society, D. C.; Dr. C. Willard Hayes, President of the Geological Survey; The Hon. S. P. Langley, Secretary of the Smithsonian Institution; Colonel Bernard H. Green, Superintendent of the Congressional Library; Admiral M. T. Endicott, U.S.N., Chief of the Bureau of Yards and Docks; The Hon. Elliot Woods, Superintendent of the U. S. Capitol; Dr. Charles W. Needham, President of the George Washington University; Right Rev. D. J. O'Connell, Rector of the Catholic University; Rev. Jerome Daugherty, President of the Georgetown University; Mr. George Westinghouse; Dr. Alexander Graham Bell; Messrs. John Joy Edson, W. C. Whittemore, and S. W. Woodward; Admiral R. E. Mason, Chief Bureau of Ordnance, U.S.N.; The Hon. Herbert Putnam, Librarian of Congress; The Hon. S. N. D. North, Director of the Census; The Hon. C. H. Keep, Assistant Secretary of the Treasury; Mr. Gifford Pinchot, Chief of Bureau of Forestry; Captain J. H. Moore, Mr. Charles J. Bell, the Hon. M. E. Ailes, and Colonel Charles Bromwell, Superintendent of Public Buildings and Grounds.

On Saturday, October 29, the party left for Washington, arriving at 12.30 P.M. They were escorted in carriages to the headquarters at the Willard Hotel. Here a luncheon was served by invitation of the Reception Committee, and a programme, having on its cover a representation of the badge worn, and containing a list of the visits and excursions, was distributed.

At 2.15 P.M. the members proceeded to the east entrance of the White House, where they were received by the President of the United States, who was accompanied by Mrs. and Miss Roosevelt. The President received the members in the "Blue Room," and spoke a few words of hearty welcome, after which the members and the ladies who attended the reception were individually presented to him and had the honour of shaking hands. The entire White House was thrown open to the visitors.

During the afternoon the members visited various points of interest. At 8.30 P.M. a reception was given by the Reception Committee in the Corcoran Gallery of Art. The entire gallery was thrown open to the inspection of the visitors. Music was furnished during the evening by the Engineers Corps band. Mrs. Thomas C. Noyes sang several selections during the reception, closing with "Annie Laurie." The members were received by Mr. William Barret Ridgely, Chairman of the Honorary Reception Committee; General John M. Wilson, representing the Corcoran Gallery; General Adna R. Chaffee, representing the army, and Mrs. Chaffee; Admiral George Dewey, representing the navy, and Mrs. Dewey; Dr. Charles D. Walcott, Director of the Geological Survey; Mrs. Walcott; and Mr. Andrew Carnegie.

Through the efforts of the Reception Committee an extraordinary privilege was accorded to the visitors, the public buildings being opened for their inspection on Sunday afternoon. At the Library of Congress the members were received by Mr. David Hutcheson, superintendent of the reading-room. At the United States National Museum and Smithsonian Institution the guests were received by Dr. Langley, secretary, and by Mr. Rathbun, assistant secretary in charge of the museum.

Special invitations were issued to the visitors for church services, and in several churches pews were reserved for their accommodation.

Monday morning again saw the party moving westward, as the train left Washington for Pittsburg at 8.30 o'clock. At Cumberland, Maryland, which was reached about noon, a stop was made for luncheon.

VISIT TO PITTSBURG.

The committees in charge of the Pittsburg reception and entertainments were as follows:—Executive Committee: Mr. Julian Kennedy, Chairman; Mr. J. M. Camp, Secretary; Messrs. C. W. Bray, F. J. Torrance, A. M. Jenkinson, John B. Jackson, Robert Pitcairn. Programme Committee: C. W. Bray, W. Lucien Scaife, Robert A. Walker, Walter M. M'Farland, John M'Leod, Emil Swensson, H. F. J. Porter, James Scott. Reception Committee: Francis J. Torrance, A. C. Dinkey, Dr. John A. Brashear, Dr. W. J. Holland, Thos. Morrison, H. J. Heinz, John C. Oliver, John Eaton, D. C. Ripley, H.

K. Porter. Entertainment Committee: A. M. Jenkinson, W. Linford Smith, J. G. Bennett, H. G. Wasson, John R. M'Ginley, Charles A. Painter, David C. Kerr. Finance Committee: John B. Jackson, W. M'Conway, W. W. Blackburn, W. N. Frew, B. F. Jones, Jr., W. P. Snyder, F. L. Robbins, Wm. Flinn, Reuben Miller, Emil Winter, John Caldwell, J. W. Friend, A. W. Mellon. Transportation Committee: Robert Pitcairn, W. H. Keech, W. L. Abbott, J. M. Schoonmaker, J. D. Callery, Col. Samuel Moody, Homer J. Lindsay, and R. A. Finney.

Handsomely bound black leather wallets were distributed among the visitors. These were adorned with a photograph of Mr. Andrew Carnegie, and contained in the various pockets pamphlets containing statistics of the industries of Pittsburg and an artistic programme of the visit. A relief map, with the various trips to be taken by the visitors indicated, was also distributed.

The figures of Pittsburg's commercial importance given were of great interest. They show that the total tonnage of the city in 1902 was 86,636,680 tons. Pittsburg also holds the record for a single day's shipment by water, 399,350 tons having been shipped on June 24, 1903. In 1902, 76,950,000 tons were transported by rail and 9,686,680 tons by water. The coal production of the district in 1902 was 36,137,346 tons, or about one-eighth of the output of the United States during that year. The production of steel during that year was 5,580,600 tons. The steel rail production was 712,300 tons. The pig iron production was 4,260,768 tons. There are 43 blast-furnaces in the district with a total annual capacity of 7,056,000 tons; 15 Bessemer converters with an annual capacity of 3,920,000 tons; 116 open-hearth furnaces with an annual capacity of 3,472,000 tons; and one Talbot furnace with a capacity of 67,200 tons. The total value of glass products in the district in 1902 amounted to $14,276,228, as compared with $17,150,975 for the remainder of the United States. In addition Pittsburg is the centre of the United States for the production of electrical machinery and railway safety appliances, steel cars, structural shapes, pipe and tubing, tin plate, crucible steel, aluminium products, coke, pickled and canned goods, and cork.

On Monday evening, October 31, the members of the Iron and Steel Institute arrived in Pittsburg, over the Baltimore and Ohio Railway, from Washington. Members of the Pittsburg Reception Committee met the party at Connellsville, and Mr. F. J. Torrance presented a letter of welcome, sealed by the Pittsburg Chamber of

Commerce. This daylight trip enabled the members to view the coking operations in the Connellsville field, several thousand of the ovens being situated along the main line of the railroad. Headquarters in Pittsburg were established at the Hotel Schenley, although a large number of the members were quartered at the Country Club and at the Hotel Henry. On Tuesday morning the Homestead Works of the Carnegie Steel Co., Homestead, Pennsylvania, were visited. Meantime the ladies in the party were taken for a drive through the parks, luncheon being served for 125 ladies at the Country Club, where they were received by Mrs. A. M. Jenkinson, Mrs. Julian Kennedy, and Mrs. Albert J. Logan. In the afternoon the members were taken to the Duquesne Steel Works. Luncheon was served on the train that carried the party from Homestead to Duquesne. Since the previous visit of the Institute members, fourteen years ago, both plants have grown to tremendous proportions. On Tuesday evening a reception was held by the Reception Committee at the Hotel Schenley, which was attended by nearly all the men of prominence in the iron and steel trades of the Pittsburg district. The reception was followed by a dance, and supper was served in the restaurant adjoining the ballroom.

The Edgar Thomson plant of the Carnegie Steel Company was visited on Wednesday morning. As on Tuesday, luncheon was served on the train, and in the afternoon the members were taken to East Pittsburg, where the great works of the Westinghouse Electric and Manufacturing Co. and of the Westinghouse Machine Co. are situated. Dinner was served in the new machine shop, the party returning at 9.30. Thursday morning was left open by the Entertainment Committee so that the members could make trips to other works in which they might be interested, many visiting the Isabella furnaces to see Mr. Gayley's method of drying the blast. At 2 o'clock on Thursday afternoon about 150 of the party left for Cleveland, while another section, numbering about 80, left for St. Louis later in the day.

Before leaving Pittsburg those members who were guests of the Country Club presented the club, through the president, Mr. A. M. Jenkinson, with a handsome tankard. The presentation was made by Mr. Cecil Allen.

On November 2, on the way to Bessemer, the train passed through the town of Braddock, close to the historical Braddock's Field, where, in 1755, General Braddock, commanding a British expedition sent out against the French at Fort Duquesne, fell into an ambush laid by the Indian allies of the French, and perished with practically his entire command. In Braddock's party was George Washington, who, in the capacity of a military surveyor, had visited the site of Pittsburg two years before. Washington then pronounced the land at the fork of the rivers at the headwaters of the Ohio "extremely well situated for a fort" and "very convenient for building." On the strength of this report Capt. Trent, with a detachment of Virginia militia, began the construction of a fort at this place in February 1754. Two months later Trent and his men were driven away by a superior French force, and the French completed the fort and named it Fort Duquesne. It was in the attempt to recapture this stronghold that Braddock fell on July 9, 1755. Three years afterwards, General Forbes, with an army of 7500 men, marched over the same route. The French, being informed of his coming, burned Fort Duquesne and fled. With the occupation of the place by Forbes, the French lost their foothold on Pennsylvania soil. It was at Forbes' suggestion that the town which sprang up on the site of Fort Duquesne was named Pittsburg in honour of England's great Prime Minister. In 1764 Colonel Boquet erected a brick block-house, or redoubt, which still stands.

THE HOMESTEAD WORKS.

On Tuesday, November 1, practically the whole party, reinforced by members of the Reception Committee, assembled at the Schenley Hotel, Pittsburg, in order to visit the works of the Carnegie Steel Co. (now belonging to the United States Steel Corporation) at Homestead and Duquesne. More than 200 persons were present, and a number of street-cars reserved for their use took them down to Homestead, a township of over 12,000 inhabitants, which had clustered round the works of that name.

At the Homestead works, which are situated on the east side of the Monongahela River, they were met by Mr. Azor R. Hunt, general superintendent, Mr. H. J. Davis, assistant superintendent, and a number of heads of departments, who acted as guides. The first place visited was the 48-inch universal mill, which is capable of rolling down 48,000 tons of plates per month. It is a reversing mill, with no features which call for particular note. After passing through this mill the No. 2 basic smelting-house was reached. Here are 16 open-hearth furnaces of 40 to 45 tons capacity, fired with natural gas. The furnaces are charged by machinery, the materials being filled into oblong steel troughs, and tipped into the furnaces by a charger of the Wellman-Seaver type. In addition to this department there are two other ranges of furnaces, No. 1 with ten 50-ton furnaces, and a building known as OH3, containing twenty-four 45-ton furnaces. The basic furnaces are lined with good quality firebrick in the usual way, and afterwards covered with material which takes the form of crushed magnesite and limestone, pulverised to the size, approximately, of a broad-bean, and spread loosely, to the depth of a few inches on the hearth and banks. No preliminary wood or coal firing is necessary, and no binding material is used; natural gas is turned in, and the heat slowly raised until a temperature well above that obtained in ordinary practice has been reached. After a wash-out charge the furnace is ready for work.

The party was next conducted to the 32-inch slabbing mill. Here large engines by E. P. Allis & Co., Milwaukee, supply the requisite power. The mill is capable of rapidly cogging ingots of 26 by 53 to 4-inch slabs. The method of shearing and cropping is interesting. One end having been cropped, the plate is lifted by a hydraulic plunger working between the live-rolls, and rotated, while thus balanced, until the other end points to the shears, whereupon the plunger falls, and the live-roller gear carries the slab forward for shearing. In this shop a number of duplex pumps are provided, and two large pumps for the supply of hydraulic power. The accumulators are of the elongated type, the falling weights being much longer, but smaller in diameter than those usually employed in English works.

The plate-mill was the next place visited. This is capable of taking slabs and cogging to plates 140 inches wide. It is a three-high mill, and is provided with a fine lifting table, raised and depressed by hydraulic plungers. The plates pass between a pair of straightening-rolls, and are skidded on to cooling beds, from which live-rollers take them part way to the shears and deliver them upon a park of castor-rolls, upon which they are borne to the shears and cut to size.

These castor-rolls present many advantages. The power required to manipulate the sheets and plates is relatively small, so that a few men with tongs can readily handle the largest sizes. Their method of distribution also affords free access by the operatives to the plates, as the men can move in and out amongst the castors with the greatest ease. Opposite the giant shears above referred to was an interesting form of machine used for shearing plates to circular discs. Traversing the stockyard the visitors were next taken to the celebrated 35-inch girder-mill. This mill, the largest of its kind, is a three-high mill, with four stands of rolls. The travelling and lifting table excited general admiration. Beyond the cogging-train are four trains of continuous rolls, the first being a roughing-mill, the second and third intermediate mills, and the fourth the finishing mill. Girders from 12 inches to 24 inches are rolled continuously in this mill, sawn, and taken direct to the stockyard. The great lifting table was designed by Mr. R. H. Stevens and made at the works.

In the next shop visited the process of hardening an armour-plate was in operation. This shop contains twelve furnaces for carburising on the Krupp system, and a water-jet hardening-tank. Beyond this shop is situated the Whitworth press and four furnaces. The ingots, carried on a porter-bar in the usual way, weigh from 90 to 100 tons, and are pressed down to plates without rolling, each ingot making two such plates. The members were also shown the cutting of an armour-plate by a 7-foot circular saw of high-speed steel. The saw is capable of cutting 3 inches per minute, and makes 1200 revolutions per minute, the periphery travelling at the rate of about 4 miles a minute.

The Homestead works cover about 156 acres of land. Some idea of the magnitude of the works may be gathered from the following data, furnished by the management: There are two 10-gross-ton Bessemer steel converters and fifty basic open-hearth steel furnaces (three 20, twenty-three 40, and twenty-four 45-gross-ton); one 200-gross-ton mixing furnace; one 28- and one 38-inch reversing blooming-mill; one three-high 33-inch and one 40-inch reversing cogging-mill; one 32-inch and one 30-inch universal slabbing-mill; one 23-inch, one 33-inch, and one three-high 35-inch train for structural shapes; one 119-inch, one 128-inch, and one 140-inch three-high sheared plate-mill; one 48-inch, and one 42-inch universal plate-mill; and one 10-inch guide-mill; 104 heating pits and 36 heating furnaces; one beam fitting shop; one steel foundry, with an annual capacity of 3300 tons of steel castings; one armour-plate plant, consisting of a press shop, with one 12,000-ton and one 10,000-ton forging press and 12 heating furnaces, a carburising shop with 13 furnaces, and a machine shop for finishing armour-plate; also a protective deck-plate plant, with one 2000-ton press and three heating furnaces. The rolling-stock consists of eighteen broad-gauge locomotives, forty-seven narrow-gauge locomotives, and 1174 cars, the combined railway mileage amounting to fifty-two miles. There are 20 locomotive-cranes and 128 electric travelling-cranes, with a total lifting capacity of 3665 tons. The electrical plant also comprises 819 motors, aggregating 21,746 horse-power. The boiler-plant consists of 208 stationary boilers, developing 44,120 horse-power. The annual capacity comprises 710,000 tons of pig iron, 425,000 tons of Bessemer steel ingots, 1,550,000 tons of open-hearth steel ingots, 1,425,000 tons of rolled products, 10,000 tons of armour-plate, and 130,000 tons of axles.

The Duquesne Works.

At the Duquesne Works the party were met by Mr. H. D. Williams, general superintendent, Mr. E. H. Hamilton, assistant general superintendent, and a number of guides. The Duquesne Steelworks and Furnaces were built in 1886-88 by the Allegheny Bessemer Steel Co., and the capacity increased in 1891 by Carnegie Brothers (Ltd.). The first blow was made in February 1889, and the first steel rolled in the following month. The works at present comprise two 10-ton converters, fourteen 50-ton basic open-hearth steel furnaces, one 50-ton mixer, thirty-six soaking-pits, and eight trains of rolls, one 10-inch, one 13-inch, one 16-inch, two 21-inch, one 26-inch, one 38-inch, and one 40-inch, and a bar reel. The annual capacity amounts to 600,000 tons of Bessemer ingots, 480,000 tons of open-hearth ingots, and 820,000 tons of finished steel. There are four blast-furnaces, with sixteen Kennedy-Cowper stoves, with a total annual capacity of 750,000 tons. The total horse-power of the boilers aggregates 31,000, and that of the engines 21,500, the fuel used being natural gas and coal.

On entering the billet stockyard the visitors passed at once to the great 40-inch bar-mill. This is a continuous mill, taking 3-ton ingots from soaking-pits in the Bessemer shop to the cogging-rolls, and passing the billets from thence through a continuous train of rolls consisting of nine stands. Halfway between the cogging-rolls and the rest of the train were situated two powerful Frank-Kneeland shears. In the Bessemer shop the visitors witnessed a blow, and then passed on to the bar-mills. It may be noted that 200 heats are made per twenty-four hours, each heat taking from twelve to fifteen minutes. The capacity of the converters amounts to 58,600 tons per month. Behind the converters is a 200-ton mixer. The visitors then traversed the 21-inch mill, which runs parallel to the 40-inch mill just described, but which is separated from the latter by another, which was not shown. The 21-inch mill is a three-high mill with two trains of rolls, each train consisting of the roughing and three succeeding pairs of housings. At the blast-furnaces the method of charging in buckets hoisted on an endless chain attracted much interest. Each furnace has 15 tuyeres, the diameter of the hearth being 13 feet 6 inches, and the height 100 feet. The pig iron is cast in a Uehling machine, and each furnace produces about 180 tons of pig iron every four hours, the four furnaces together making 74,500 tons of pig iron per month. The following records were posted at the furnaces :—

Daily tonnage . . for 1 furnace = 793, October 27, 1904.
,, ,, . . 4 furnaces = 2,700, October 27, 1904.
Weekly ,, . . 1 furnace = 5,001, October 22–29, 1904.
,, ,, . . 4 furnaces = 17,783, October 22–29, 1904.
Monthly ,, . . 1 furnace = 26,659, October 1904.
,, ,, . . 4 furnaces = 74,606, October 1904.
Greatest monthly tonnage produced in any 4 furnaces, irrespective of the works in which they are situated . . = 74,189, January 1902.
Total product of 1 furnace for one lining . = 1,287,381 {No. 1 furnace, 1896 to 1903.
Total product of one lining for 4 furnaces = 4,469,855 {Nos. 1 to 4 furnaces, 1896 to 1903.

The power-house, in which were situated five large Allis-Chalmers engines, was next visited, and the party then traversed the basic open-hearth building, in which are placed fourteen 50-ton furnaces.

THE EDGAR THOMSON WORKS.

A number of members of the Institute visited the Edgar Thomson Steelworks and Blast-furnaces on Wednesday, November 2, two special trains being despatched from Union depôt. Mr. A. C. Dinkey, President of the Carnegie Steel Company; Mr. C. E. Dinkey, general superintendent at Braddock; Mr. James Gayley, First Vice-President of the United States Steel Corporation; Messrs. H. Scott, James M. Camp, and other officials of the Carnegie Company escorted the visitors through the works. On arrival the party was hailed by the Carnegie Library Band, which played national anthems and popular airs. The principal point of interest was the rail-mill, where most of the time was spent, the guests being especially interested in the Kennedy-Morrison method of cooling steel rails. Both Mr. Julian Kennedy and Mr. Morrison were there to explain the method.

The annual capacity of the rail department is 650,000 tons. The record run for twenty-four hours is 2929 tons, or 94,000 rails. The annual output of steel ingots is 1,000,000 tons. The party then journeyed to the blast-furnaces, where 1,460,000 tons of pig iron are turned out annually. The first of the furnaces was completed within seven months, while the blowing-engine house, 80 feet high, 150 feet long, 60 feet wide, and containing about 300 tons of material, was erected complete in exactly one week. In this building the members were shown five large Allis-Chalmers compound blowing-engines, each having a horse-power of 1700. Then they inspected the twenty-six 250 horse-power Cahall vertical water-tube boilers, which, owing to their exposed condition, were easily available for close scrutiny. The eleven blast-furnaces were next visited, and the point which interested most was that the furnaces, which were originally built 105 feet in height, had been cut down to 90 feet, as practice has shown the smaller furnace to give greater efficiency. Considerable interest was shown in the eight huge settling tanks, in each of which some 158,000 gallons of water is stored. These are each 33 feet high and 28 feet in diameter. The fact that 40,000,000 gallons of water is used in the works in the course of twenty-four hours attracted considerable attention. In passing over to the trains interest centred in the hot-metal trestle, which permits the ladles containing the molten iron to pass uninterrupted from the blast-furnaces to the steel plant. The latter consists of four 15-ton Bessemer steel converters, four spiegeleisen cupolas, one 50-ton metal mixer, seven pit furnaces, seven Siemens heating furnaces, one three-high 40-inch blooming, and two three-high 23- and 27-inch rail-mills, forges and foundries. The annual output is 1,000,000 of steel ingots, 650,000 tons of rails, billets, and sheet bars, and 50,000 tons of iron and brass castings. There are eleven blast-furnaces using Connellsville coke and Lake Superior ores, and six Uehling pig iron casting machines. The annual make amounts to 1,460,000 tons.

THE WESTINGHOUSE WORKS.

Although to an Institute concerned with the metallurgy of iron and steel the Carnegie Works were, naturally, of first importance, the Westinghouse Electric and Manufacturing Company's establishment at East Pittsburg was hardly of secondary interest. The visit to these works was paid on the afternoon of Wednesday, November 2.

At the Westinghouse plant the party was met by Mr. George Westinghouse, Mr. Thomas, vice-superintendent, Mr. W. A. Bole, general manager, Mr. W. F. Zimmerman, and Mr. J. Gavin. A trip was made through the plant of the Westinghouse Machine Company, and the keenest interest was manifested in the building and testing of the Westinghouse steam-turbine and gas-engine. The party was then escorted to the great electric plant, and machine tools on the ground floor, and subsequently to the wiring and core-winding departments above. The Westinghouse Electric and Manufacturing Company was organised for the manufacture of electrical apparatus eighteen years ago, when electricity as a form of energy first began to assume a commercial aspect. Its growth and development have been scarcely less marked than has been the development of electricity itself. Since 1886, with a working force of 200 men, it has grown in the comparatively short period of eighteen years to be one of the largest manufacturing institutions in the world, employing at the present time, in the main plant alone, 10,000 persons, and having over forty-seven acres of floor space. The main plant is situated at East Pittsburg, twelve miles east of the city of Pittsburg, on the main line of the Pennsylvania Railroad. In addition to this, it has, in the United States, important branch factories at New York, Cleveland, Pittsburg, Newark, New Jersey, and Bridgeport, Connecticut, in addition to affiliated plants in Europe. The products of the Westinghouse Electric and Manufacturing Company vary from small and delicate measuring instruments to the largest electrical machines that have ever been built. Generators are built in capacities ranging from ½ kilowatt to 5000 kilowatts; transformers from ¼ kilowatt to 2750 kilowatts, and motors from ¼ horse-power to 2000 horse-power.

Special mention should be made of the electrical equipment furnished by this Company for the New York Rapid Transit Company. Eight electrical generators, each having a capacity of 5000 kilowatts, were made for the Manhattan division, and nine others of the same type and capacity were contracted for by the New York Rapid Transit Company for its Subway division.

Organised in 1881 with a working force of ten men, the Westinghouse Machine Company has grown to such an extent that it now builds the largest steam and gas power machinery necessitated by the commensurate advancement of electrical generating and motive power apparatus. Its works at East Pittsburg and Trafford City, Pennsylvania, and Cragin, Illinois, cover an aggregate area of nearly 50 acres, with a working floor area of 20·4 acres; and a total working force of 3500 men is employed. The product consists of single-acting steam-engines, 5 to 500 horse-power; double-acting steam-engines of the Corliss and high speed marine types, 500 to 10,000 horse-power; single-acting gas-engines, 10 to 300 horse-power;

double-acting gas-engines, 200 to 4000 horse-power; steam-turbines, 200 to 15,000 horse-power, and mechanical stokers for all stoking applications and for handling all kinds of coal. The annual output of the engine department is 230,000 horse-power, and of the stoker department 140,000 horse-power.

In the evening the Company entertained the members at a banquet, which was given in the largest aisle of the works, the length of this aisle being about one-third of a mile. The portion of the aisle set apart for the banquet was decorated with flags of the United States and Great Britain, and the floral decorations were of great beauty. The lighting effects were remarkable. Bremer lamps were strung from the ceiling, and Cooper-Hewitt lamps were suspended from the sides, this latter effect making possible the taking of a number of photographs. A lounging room was provided for the convenience of the guests, where writing materials and souvenir postal cards, showing the interior and exterior views of the works, were provided. A souvenir in the form of a miniature induction motor was presented to each guest. At the conclusion of the banquet Sir James Kitson, Bart., Past-President, proposed the health of Mr. Westinghouse, and took the opportunity to thank the city of Pittsburg for the kindness shown to the members. Mr. George Westinghouse responded briefly, stating his great pleasure in being honoured by the presence of so many distinguished visitors from abroad.

THE ISABELLA FURNACES, ETNA.

Opportunity was given for visiting the Isabella Furnaces, to inspect the air-drying by refrigeration described in Mr. Gayley's paper, and on November 2 many members took advantage of the facility offered of seeing this important plant. The magnitude of the plant, and the enterprise and confidence that had led to experimenting on such a magnificent scale, aroused great interest. The ammonia-compressing plant, the brine-tanks, the miles of snow-covered pipe in the refrigerating-chamber; the arrangements for thawing off the snow deposit when it gets so thick as to impair efficiency; for testing the humidity of the air at the intake and at the outlet; for taking and recording the temperature in the chamber, all showed how carefully the experiment has been carried out, and already some interesting data have been accumulated in reference to the relation of humidity and season. The coils only want thawing every three or four days to remove the deposited moisture, and this is done in sections, so that only a slight increase in temperature of the entire chamber results, and is duly visible in the temperature diagram. The engines were working evenly and steadily, but when the atmosphere is moister they have to go quicker, whilst on very cold days they need not work at all. The air is forced into the coil-room by an electrically-driven fan; the blowing-engines act as exhausters, and draw the dried air out. The rate of passage through this refrigerating-chamber depends upon the original humidity of the air, being slower the higher the content of moisture to get the same degree of desiccation. Mr. Gayley's paper contains a full description of this plant, which, however, has to be seen to realise the large scale upon which this experiment has been made. There are three furnaces, No. 1 and No. 3 being in blast at the time of the visit. The furnaces are 90 feet high by 21 feet, their total annual capacity being 290,000 tons of pig iron. Each furnace is provided with four 90 feet by 21 feet Kennedy stoves, and has the usual large allowance of tuyeres, water-cooled boshes and hearth, Brown skip-charges, four down-carriers, and large dust-catchers. The slag is discharged on to travelling trays, which are cooled by jets of water, and the slags loaded directly into railway trucks. The metal is run into ladles, and taken away to a large casting machine a little way off.

THE YOUNGSTOWN WORKS.

A small party of members visited the Youngstown Works of the Carnegie Steel Company on the Ohio River. At these works, known as the Upper and Lower Union Mills, the visitors were received by Mr. I. W. Jenks, general superintendent, and Mr. E. Coombs, general superintendent of the Valley District of the Carnegie Steel Works. The first place inspected was the Morgan continuous hoop-mill. This is a 10-inch mill, consisting of six stands of rolls, one behind the other, and carefully speeded in the usual way to take up slack. The mill is intended to take $1\frac{1}{2}$-inch billets, and roll them down to strip $\frac{3}{4}$ by $\frac{1}{4}$ inch. The rod is cropped by flying shears, and then passes to three pairs of finishing rolls, being reduced at the last pass to $\frac{15}{16}$ by 19 American gauge, and lengths of 1900 feet, the strip passing through a long system of water-cooled guides, and being ultimately reeled into coils. The coils are taken to a combined straightening machine and flying shears, cut into the requisite lengths, and bundled. A feature of interest was the ingenious method adopted between the three last stands of finishing rolls for the purpose of taking up slack. A lever-arm is attached to the housings, having a roller at one end, and being weighted at the other. The roller bears upon the underneath side of the strip, holding it taut. The arrangements for galvanising are also of interest, the coils being let down on pegs into the galvanising vat by means of a system somewhat resembling an Archimedean screw. At the Upper Union Mill, which has an annual capacity of 150,000 tons of miscellaneous sections, there are five gas furnaces, and four mills, one 7-inch, one 8-inch continuous, one 10-inch continuous hoop, and one 12-inch finishing train of rolls. At the Lower Union Mill the plant consists of ten single and eighteen double puddling furnaces, nine reheating furnaces, and nine trains of rolls. The annual capacity of small sections, hoops, and cotton-ties, &c., is 125,000 tons.

THE JONES & LAUGHLIN STEEL COMPANY.

A party of over fifty members, amongst whom were Sir James Kitson, Bart., Past-President, and Mr. W. Whitwell, Past-President, visited the works of the Jones & Laughlin Steel Company on November 3. The members, who were introduced by Mr. B. Talbot, were received by Mr. B. F. Jones, Jun., the president of the company, Mr. Willis L. King, vice-president, and Mr. W. L. Jones, general manager. Since the previous visit of the Institute in 1890, the whole plant had practically been renewed, while further important extensions are in contemplation. The tonnage has risen to well over 1,000,000 tons of steel per annum, a fact which illustrates the progress made in the works. The visitors were shown the Talbot continuous steel process. After having found the present furnace, one of 200-tons capacity, to work well, the company are now putting down four additional furnaces of similar capacity, which will raise the output from this source alone to more than 300,000 tons per annum. The visitors were shown the operation of charging molten metal into the large bath, and were much interested on observing the intense reaction which follows. The metal, which contains about 0·1 per cent. of phosphorus, is taken from the mixer which supplies the charge for the Bessemer converters, and after about four hours' working is tapped out, 50 tons at a time, the steel containing only about 0·01 per cent. of phosphorus and 0·03 per cent. of sulphur. The furnaces are fired, as is usual in the Pittsburg district, with natural gas.

The visitors were then taken to see the Bessemer shop and mills. The product of the works is of a varied nature, and includes angles, girders, and structural material generally, in addition to blooms and billets, sheets, plates, &c. They were also taken by Mr. Thomas Robbins, Jun., to inspect the interesting equipment of automatic belt conveying machinery, used chiefly in the coke handling and crushing department. Mr. Robbins provided the members with suitable dust coats and hats, so that a minute examination of the machinery, which was made by the Robbins Conveying Belt Company, was possible.

The company possesses six blast-furnaces, four of which are 100 feet by 22 feet, and twenty Siemens-Cowper stoves, the annual make amounting to 1,035,000 tons of pig iron. The Bessemer department comprises three 10-ton converters, four cupolas, and thirty-four soaking-pits, and produces 800,000 tons of ingots. The open-hearth plant consists of the Talbot furnace already referred to, and one 25-ton acid and six 40-ton basic furnaces, with an annual capacity of 250,000 tons. The company also own works at Soho, Pittsburg, and elsewhere.

VISIT TO CLEVELAND.

The following is the Executive Committee which contributed so largely in making the stay at Cleveland a success: Messrs. S. T. Wellman (chairman), Alexander E. Brown, A. I. Findley (secretary), H. W. Lash, Wm. M'Lauchlan, Wm. G. Mather, James R. Mills, Jun., Robert W. Ney, John A. Penton, F. A. Scott, J. W. Seaver, and W. R. Warner.

The Reception Committee comprised the members of all other committees, together with representatives of the following: Acme Machinery Co.; Avery Stamping Co.; W. Bingham Co.; Harvey H. Brown & Co.; Chase Machine Co.; William Chisholm & Sons; Cleveland City Forge & Iron Co.; Cleveland Foundry Co.; Cleveland Furnace Co.; Cleveland Galvanising Works Co.; Cleveland Hardware Co.; Cleveland Punch and Shear Co.; Cleveland Steel Co.; Cleveland Twist Drill Co.; Corrigan, McKinney, & Co.; Eberhard Manufacturing Co.; Electric Controller and Supply Co.; Empire Rolling Mill Co.; Grasselli Chemical Co.; W. A. Hawgood & Co.; Lamson & Sessions Co.; Lucas Machine Tool Co.; Mitchell & Co.; National Acme Manufacturing Co.; National Carbon Co.; National Malleable Castings Co.; Ohio Foundry Co.; Penn Iron and Coal Co.; Pittsburg

Coal Co.; Pittsburg & Lake Angeline Iron Co.; Republic Iron and Steel Co.; John A. Roebling's Sons Co.; Rogers, Brown, & Co.; Arnold C. Saunders; Sherwin-Williams Co.; Strong, Carlisle, and Hammond Co.; Struthers Furnace Co.; W. S. Tyler Co.; Union Steel Screw Co.; Universal Drafting Machine Co.; Upson Nut Co.; Upson-Walton Co.; H. S. Wilkinson; and Messrs. Wyman & Gordon.

The Finance Committee consisted of Messrs. Wm. G. Mather (chairman), R. F. Bourne, A. S. Chisholm (treasurer), Harry Coulby, H. G. Dalton, H. W. Lash, E. W. Oglebay, and W. P. Palmer.

The Banquet Committee was composed of Messrs. Alex. E. Brown (chairman), Wm. G. Mather, F. C. Osborn, John A. Penton, Ambrose Swasey, James C. Wallace, and C. H. Wellman.

The Hotel Committee consisted of Messrs. J. W. Seaver (chairman), George Bartol, and F. G. Tallman.

The Luncheon Committee consisted of Messrs. H. W. Lash (chairman), and H. A. Barren, G. W. Carpenter, and T. R. Morgan.

The Publication Committee consisted of Mr. A. I. Findley (chairman), and Messrs. W. W. Wallace, and E. C. Baxter.

The Railroad Committee comprised Mr. R. W. Ney (chairman), Messrs. J. A. Coakley, Chas. A. Gallagher, T. B. Hamilton, J. T. Johnston, H. W. Lash, and J. Kirk Russell.

There was also a Ladies' Committee, consisting of Mr. James R. Mills, Jun., chairman; and Messrs. William F. Bonnell, Alex. E. Brown, D. B. Chambers, H. G. Dalton, L. H. Elliott, C. T. Johnston, W. P. McMurray, Launcelot Packer, Charles A. Post, J. H. Sheadle, and C. A. Vogt. This committee was helped by the Auxiliary Committee of Cleveland Ladies, consisting of Mrs. Charles E. Adams, Mrs. George Bartol, Mrs. C. C. Bolton, Mrs. W. F. Bonnell, Mrs. Alexander E. Brown, Mrs. Harvey H. Brown, Mrs. D. B. Chambers, Mrs. A. S. Chisholm, Mrs. H. G. Dalton, Mrs. R. A. Harman, Mrs. C. G. Hickox, Mrs. James H. Hoyt, Mrs. John G. Jennings, Mrs. H. W. Lash, Mrs. M. J. McMurray, Mrs. D. Z. Norton, Mrs. W. P. Palmer, Mrs. C. J. Sheffield, Mrs. Ambrose Swasey, Mrs. James C. Wallace, Mrs. W. R. Warner, Mrs. Chas. H. Wellman, and Mrs. S. T. Wellman.

The members arrived at Cleveland on November 3, at 4.30 o'clock, over the Pennsylvania Railroad. From Pittsburg they were accompanied by the following members of the Cleveland Reception Committee: Messrs. A. I. Findley, H. W. Lash, S. T. Wellman, F. G. Tallman, W. F. Bonnell, and R. W. Ney. Many other members of the Reception Committee met the train at the Euclid Avenue Station, from which four special electric cars conveyed the visitors to the Hollenden Hotel, where an informal reception was held.

The programme distributed among the members was tastefully executed, and contained a number of views of Cleveland, together with useful notes relating to the works to be visited, and information of a general and statistical character relating to the city.

Cleveland has about 450,000 inhabitants, and covers 35 square miles. It was settled in 1796 by a party of engineers, headed by General Moses Cleaveland, making a survey for the Connecticut Land Company. The frontage of the city on Lake Erie is approximately 10 miles, and there is an improved harbour frontage of about 16 miles on either side of the Cuyahoga River. For obvious reasons Cleveland has been known as the "Forest City." Its wooded parks contain 1500 acres, connected by 30 miles of boulevards. Among the manufactures in which the city takes first rank in the United States are wire and wire nails, coal and ore-handling machinery, heavy forgings, bolts and nuts, carriage hardware, malleable iron castings, vapour stoves, electric carbons, and paints. The district of which Cleveland is the centre can assemble coke, ore, and flux for the manufacture of pig iron at a less cost than any other district in the United States. Centred here are the Lake Superior iron ore interests, including selling firms, vessel owners, dock and transportation companies, making Cleveland the greatest iron ore market in the world. In 1903 the various ports on the south shore of Lake Erie received 19,681,731 tons of Lake Superior ore. Of this amount 5,424,650 tons were unloaded on the docks of Cleveland and the tributary port of Lorain.

On Friday morning, November 4, a special train conveyed the party to the Newburgh Mills of the American Steel and Wire Company. Mr. Robert W. Ney, general manager, welcomed the guests to the works. The various departments were visited, and luncheon was served in one of the buildings. In the afternoon the train proceeded to the plant of the Cleveland Furnace Company. The members were shown the three new type Mesta blowing-engines, which contain the air-cylinder on one housing and the steam-cylinder on the other. They witnessed a cast. The greatest feature of interest, however, was the skip-loading department, where the electrically operated lorry collects the charge from the various bins. This apparatus was built by the Brown Hoisting Machinery Company, and the taking of an

1800-pound charge, consisting of five different kinds of ore, in three minutes, was witnessed. One man operates the entire plant. The Brown ore bridge, 440 feet long, and operating on a 1500-foot runway, was another feature which attracted much attention.

The party was then conducted to the Central Furnaces, and a stop was made to inspect the new Scherzer rolling lift-bridge, which spans the Cuyahoga River along the line of the Newburgh and South Shore Railway. At the Central Furnaces three blast-furnaces were seen. Two new furnaces are in course of construction. The molten metal is conveyed from the furnaces at this plant to the Newburgh Steelworks, a distance of five miles. The arrival of a train of metal was witnessed during the visit. The ore handling plant, which has recently been installed and consists of four Hoover & Mason machines, was inspected very carefully. The steamship *Mesaba* was being unloaded at the time, and this afforded an excellent opportunity for studying this operation. On the evening of Friday, November 4, a dinner to both ladies and gentlemen was given by the Reception Committee of Cleveland in the Chamber of Commerce Hall. This is a fine building, and was most beautifully arranged, tables, each accommodating eight guests, being set out on the floor of the hall and most profusely decorated with flowers. This dinner was indeed one of the most memorable occasions during the whole visit.

Saturday morning, November 5, was devoted to optional excursions to the manufacturing plants of the city, the following plants being visited: American Shipbuilding Company, Brown Hoisting Machinery Company, Cleveland City Forge and Iron Company, Cleveland Furnace Company, Cleveland Punch and Shear Company, Cleveland Steel Company, Electric Controller and Supply Company, Empire Rolling Mill Company, National Acme Manufacturing Company, National Carbon Company, Otis Steel Company, Limited, River Furnace and Dock Company, Sherwin-Williams Company, Union Rolling Mill Company, Warner & Swasey Company, Wellman-Seaver-Morgan Company. Visits were also paid by small parties to the Case School of Applied Science, where the visitors were received by Dr. C. S. Howe, the President, and by Professors C. F. Mabery, J. W. Langley, D. C. Miller, and A. W. Smith, and to the Western Reserve University.

The ladies of the Iron and Steel Institute party were taken a delightful drive through the city on November 4. They left the Hollenden at 10.30 o'clock and drove along Euclid Avenue to the boulevards and Wade and Gordon Parks, visiting the Garfield

Memorial and other points of interest. At one o'clock a luncheon was given in their honour at the Euclid Club, on Euclid Heights.

In the afternoon Mrs. S. T. Wellman entertained the ladies at tea. The house was beautifully decorated with flowers, and an orchestra played during the reception. The party left Cleveland at mid-day for Conneaut.

AMERICAN STEEL AND WIRE COMPANY, CLEVELAND.

On Monday, November 7, the members visited the works of the American Steel and Wire Company, where they were received by Mr. R. W. Ney, the general superintendent. The company owns three sets of furnaces, the Central, the Emma, and the Newburgh. The first has three blast-furnaces, one 75 feet by 20 feet, one 80 feet by 20 feet, and one 100 feet by 22 feet. Two of these furnaces have been pulled down, but others to replace them are in course of erection. The Emma Furnace is 73 feet by 17 feet, and dates back to 1872, but has been remodelled at various times. At Newburgh there is one furnace, built in the same year, 62 feet by 16 feet. It was rebuilt some years ago. The furnaces use Lake Superior ore, in a finely divided state, containing between 50 and 60 per cent. of iron. The product is Bessemer pig iron, which is converted in the Newburgh Works. The ore is brought by steamers, and raised in Hulett buckets straight from the hold, by four Hoover & Mason machines, which, at the time of the visit, were building up huge stores of ore in preparation for the winter, when navigation is closed. The whole plant is worked electrically. Another very interesting conveying plant was also seen in operation, taking ore dumped from waggons in a siding, and piling it up for winter use. It was made by the Brown Hoisting Machinery Company, and consists of a gantry, 440 feet long, supported on three lofty trestles which run on three lines of railway over the ore field. The whole gantry can be swung horizontally about the centre trestle, which remains at rest whilst the other two are caused to travel in opposite directions, the movement of the ends of the gantry being 90 feet in either direction from the central position. This ore handler has a 5-ton bucket operated by four wire ropes, and is directed entirely by one man, who can handle as much as 3000 tons per day.

The ore is charged into the blast-furnaces by an electric machine, made also by the Brown Hoisting Machinery Company, the arrangements being similar to those in operation at the Susquehanna furnaces.

The iron produced in these furnaces is conveyed in a molten condition to the Newburgh Works, where there are two large Bessemer converters of an annual capacity of 525,000 tons of ingots, four Wellman-Seaver open-hearth rolling furnaces of 50 tons gross capacity, and one stationary open-hearth furnace. The appliances for handling material are excellent. The ladles, charged with steel from the converters, are handled by a hydraulic crane of special design constructed by the Alliance Manufacturing Company of Ohio. It consists of a heavy column built up of plates and angles, standing vertically between the two converters. It supports by powerful ties a horizontal arm which, whilst remaining horizontal, can be raised and lowered several feet. On this arm runs a little bogie controlled by a hydraulic cylinder. The centre column, with the arm, bogie, and ladle, can be readily rotated, so that the ladle may be placed under the converter for filling, or swung through 90 deg., and raised till it is over the ingot moulds. The soaking-pits are in close proximity; they are served by three electric cranes, all provided with long vertical rams sliding through guides, and raised or lowered by rack and pinion. Two of these are provided with claws for seizing the hot ingot and lowering it into or removing it from the pits; the third has means for grasping the moulds and stripping the ingots. The covers of the soaking-pits are slid on and off hydraulically. From the pits the ingots are conveyed across the shop on a little conveyor to the cogging mills, where they are broken down to 7 inch by 8 inch, and then to another mill, where they are reduced to 4 inch by 4 inch or 5 inch by 5 inch, and sheared up into lengths suitable for the rod mills, to which they are carried on a suitable conveyor, which deposits them on the travelling belt of an Allen furnace. On this belt the billets, which weigh 158 lb., lie touching one another, and as they travel up the incline and slowly through the furnace they are brought up to the necessary heat for rolling. They drop from the furnace, one about every ten seconds, on to another conveyor, which takes them right up to the rod mills. When small sections are being rolled, the end of the rod from the last rolls is led into a vertical column, which rotates rapidly, and has a short arm inclined slightly downwards, through the centre of which the rod emerges, and is thrown out centrifugally beyond a number of steel pins or plungers projecting from an inclined plate and arranged in a circle, in a red-hot condition; it is thrown round the pins, just as a rope might be thrown round them, and a coil is formed. As each coil is completed the operator pulls a lever, which withdraws the pins or plungers from its centre and allows it to slide down the inclined plate on to a conveyor, which pushes it up an incline, where a passing hook on a travelling rope catches it and bears it off to the pickling tanks.

The tanks are arranged in a row, three containing acid, one water, and one coating mixture. The coils as they come in are hung on rods, which are then rested on two crutches in a pair of large, slowly revolving wheels, which carry them up and deposit them in the liquid, through which they are moved slowly, rod and all, by a conveyor, till the crutches on another similar pair of wheels pick up the rod and its burden, raise it out of the one tank and drop it into the next, where the process is repeated.

At the Newburgh Works the open-hearth furnaces have an annual capacity of 143,000 tons of ingots; the large mill can turn out 440,000 tons of blooms, billets, and slabs per year; a new blooming-mill has an annual output of 220,000 tons, and the rod mill 100,000 tons. The American Works, which has 2272 wire-drawing blocks, can turn out 125,000 tons of rods and 60,000 tons of wire; the Consolidated Works can produce 95,000 tons of rods, 80,000 of wire, and 1,100,000 kegs of nails every twelve months; and finally the H.P. Works, where wire nails are made, produce 60,000 tons of rod, 90,000 tons of finished products, and 1,100,000 kegs of nails annually.

SCHERZER LIFT-BRIDGE.

In the course of the trip members passed over the Rolling Lift-Bridge of the Newbury and South Shore Railway Company, the train being stopped after the passage across the bridge had been made, when the span was lifted for the benefit of the members. The movable span is 160 feet, the total length of the bridge being 265 feet. The weight of the superstructure is 1500 tons, and the weight of the moving parts 1225 tons; there are 800 tons of counterweights. The amount of structural steel employed is 700 tons. The bridge was designed to carry two 177½-ton locomotives, followed by a uniform load of 5000 lb. per lineal foot on each track, the factor of safety being five. The span is raised as a bascule bridge by two 50 horse-power continuous-current electric motors, the power actually used on ordinary occasions being 20 horse-power. There is an ingenious interlocking mechanism for the tracks, and this is so arranged that the bridge cannot be opened until the signals and derailing switches are so set as to prevent the passage of trains.

OTHER WORKS AT CLEVELAND.

A number of works in Cleveland were thrown open to the inspection of members. Many of these were of very great interest, the difficulty here, as elsewhere, being that time was too short to give adequate attention to them.

The following notes were furnished to the members:—

Brown Hoisting Machinery Company.—Engineers, designers, and manufacturers of special hoisting and conveying machinery and appliances for docks, railways, steelworks, blast-furnaces, shipyards, factories, mines; offices and works covering an area of 423,000 square feet. Main building and electric power-house, constructed of iron, steel, cement, and glass, are absolutely fire-proof and are fully equipped with modern high-speed electric cranes, tools and appliances.

Cleveland Furnace Company.—One furnace, 85 feet by 20 feet, built in 1902–3 and blown in August 21, 1903; four Julian Kennedy two-pass stoves, each 20 feet by 90 feet; fuel, by-product coke; ore, Lake Superior; product, foundry, malleable Bessemer and basic pig iron; annual capacity, 16,000 tons. Brand, "Cleveland." Connected with the furnace are by-product coke-ovens with an annual capacity of 120,000 net tons.

Cleveland Hardware Company.—Built in 1879; destroyed by fire in June 1891, and entirely rebuilt; two heating furnaces with two Duff gas-producers and one 10-inch train of rolls; product, shapes for waggon, carriage and sleigh hardware rolled from soft steel; annual capacity, 16,000 tons. Fuel, bituminous coal and manufactured gas.

Cleveland Steel Casting Company.—Built in 1893; first steel made January 9, 1895; two acid open-hearth steel furnaces (one 15- and one 25-gross-ton); product, steel castings; annual capacity, 11,000 tons. Fuel, natural gas.

Cleveland Steel Company.—Built in 1853 and rebuilt in 1873 and 1891; remodelled in 1894; four heating furnaces, two box annealing furnaces, and two trains of rolls containing two plate and two sheet mills; product, light steel plates and sheets; annual capacity, 30,000 tons. Fuel, producer-gas and coal.

Cleveland & Pittsburg Rail Road Docks.—Whisky Island. One plant of twelve legs, five plants of three legs each, and four plants of four legs each, all arranged so as to be moved to suit any number of hatches. The twelve-leg plant is equipped with Hulett clam-shells and Andrews scrapers. One Hoover & Mason six-leg clam-shell automatic unloading plant.

Empire Rolling Mill Company.—Built in 1900, and first put in operation Dec. 15, 1900; two puddling furnaces, six busheling furnaces, one forge fire, two gas heating furnaces, and two trains of rolls (one 12-inch roughing and one 10-inch Belgian); product, iron and steel bars; annual capacity, 20,000 tons. Fuel, manufactured gas.

Lake Erie Iron Company.—Rolling-mill added to a bolt and nut factory in 1899–1900, and first rolled products turned out Sept. 28, 1900; eight single puddling furnaces, two coal-heating furnaces, and two trains of rolls (one 18-inch muck and one 10-inch finishing); product, bar iron, all consumed by the company in the manufacture of bolts and nuts; annual capacity, 31,600 tons of bar iron. Fuel, coal in the rolling-mill and oil in the bolt and nut works.

N. Y. P. & O. Docks.—Eight Brown plants of three rigs each. All are portable and can be divided up in any way desired; three Hoover & Mason clam-shell machines with storage pockets of 3000 tons capacity.

Otis Steel Company, Limited.—Built in 1873–74 and put in operation Jan. 1, 1875; nine Siemens heating furnaces, five hammers, ten open-hearth steel furnaces (two 10-gross-ton acid, with an annual capacity of 15,000 tons of ingots, and five 18- and three 25-gross-ton basic, with an annual capacity of 80,000 tons of ingots), and three trains of rolls (one 30, one 31, and one 34-inch); product, steel plates, bar steel, forgings, and castings; annual capacity, 50,000 tons of rolled products, 15,000 tons of forged products, and 10,000 tons of castings. Fuel, coal and producer-gas.

River Furnace & Dock Company,—One furnace, 73 feet by 17 feet, built in 1879; remodelled in 1889 and 1895; rebuilt in 1902; three Foote stoves; fuel, Connellsville coke; ore, Lake Superior; product, Bessemer, foundry, forge, and malleable pig iron; annual capacity, 75,000 tons.

Union Rolling Mill Company.—Built in 1866–67; one double and six single puddling furnaces, seven single scrapping furnaces, five heating furnaces with Duff gas producers, four trains of rolls (8 and 9-inch guide, 18-inch bar, and three-high muck), and one squeezer; product, nut, bolt, bridge, and rivet iron, soft steel bars, bar iron, and shafting; specialties, "Union Refined" bar and cold-straightened shafting; daily capacity, 175 tons of finished iron. Fuel, coal and manufactured gas.

Warner & Swasey Company.—The manufacture of machine tools for brass or iron work, and high-grade astronomical and other instruments of precision.

Wellman-Seaver-Morgan Company.—Machine shop with central span and three side floors (two gallery); structural shop, pattern shop, blacksmith's shop, forge shop, &c. Steel foundry contains one 20-gross-ton basic, open-hearth furnace, annual capacity, 6000 tons. Fuel, natural gas and oil. Product of Cleveland works and of works at Akron, Ohio.—Machinery for steel and iron works, Wellman patent charging apparatus, ore and coal handling machinery, electric cranes, gas producers, power machinery (steam, gas, water), mining machinery, coke-oven machinery.

BANQUET AT CLEVELAND.

A most delightful function was the banquet tendered to the members on Friday evening, November 4, by the Cleveland Reception Committee. It was held at the Chamber of Commerce, which was decorated profusely with red, white, and blue, the British flag and the American flag hanging together round the hall. The floral decorations were also beautiful. Mr. James H. Hoyt presided, and proposed the toasts, and responses were made by Mr. Bennett H. Brough, who spoke of "Fourteen Years After," tracing the changes since the Institute's previous visit; Mr. E. Windsor Richards, who was assigned the toast, "Cleveland a Name of Good History and Prophecy in the Iron Trade in Two Countries"; Mr. E. P. Martin, who spoke on the "Future of the World's Iron Trade"; Mr. Charles Kirchhoff, who responded to the toast "The Personal Equation in the Industrial Problem," and said that one of the great problems of the future was to provide leaders; Mr. James Gayley, who spoke of "The Lake Region as a Factor in American Development," and gave interesting details relating to the growth of the ore trade, and compared the present tonnage with that of fifty years previously; and Hon. Theodore E. Burton, Member of Congress, who commented on "The Disappearing Barriers between Nations." A very handsome *menu* was provided, the cover of which bore a design representing a British steelworker clasping the hands of an American worker. The inside was ornamented by etchings representing the meeting between America and England, exemplified by the traditional John Bull and Brother Jonathan, accompanied respectively by the British lion and the American eagle. In addition to the speakers, there were seated at the top table Mr. S. T. Wellman, Mr. A. I. Findley, Mr. A. E. Brown, Mr. W. G. Mather, Mr. R. W. Ney, Mr. Ambrose Swasey, and Mr. D. G. Keller. The total number of ladies and gentlemen present was 250.

THE CONNEAUT ORE DOCKS.

On the way from Cleveland to Buffalo, on the afternoon of Saturday, November 5, a stop was made at Conneaut, to enable the party to see the great ore docks, and ore and fuel handling appliances. The weather was, for the first time since the members had landed on the American continent, somewhat unpropitious, and rain fell during the greater part of the visit. Two tenders took the members out on the waters of Lake Erie and past the great Hulett machines and the Brown electrical machines, which had, a few months previously, established a record in the annals of ore-handling, when the steamer *Augustus B. Wolvin*, carrying a cargo of 9945 tons, was cleared completely in four and a half hours. The actual working time was, however, only four hours and six minutes, during which the four Hulett clam-shell machines withdrew 7257 tons; the Brown hoisting-machines, which were at work during the shorter period of three hours and forty-one minutes, took out 2688 tons. After witnessing the clearing of ore from one of the steamers lying by, the party was taken to see the coal-tipping plant. Here the waggons, holding up to 50 tons, are lifted bodily on a platform and tilted over into the funnels of the shoots, which convey the contents to the steamer holds.

The plant consists of four 5-ton electric elevators and a 7½-ton Stockbridge, built by the Brown Hoisting Company. In these machines the grabs are dropped on to the ore-piles, and raised and manipulated by ropes. There are also four 10-ton Hulett steam hydraulic machines, the feature of which is a great beam, having a solid plunger at one end, terminating in a grab, which acts in its descent much as do the other machines. These were built by the Wellman-Seaver-Morgan Company. There is also a Hoover & Mason machine. After inspecting all the machines the party returned into the original starting-point, whence they again boarded the waggons and were taken back to the station.

An interesting illustrated pamphlet on the growth of the ore trade was presented to each member by the Pittsburg and Conneaut Dock Company. The ore trade of 1903 was one-hundred-fold greater than in 1864, and fifty times what it was in 1869. The shipments in 1855 amounted to 1449 tons, and in 1903 to 24,281,595 tons. The largest cargo of ore carried on the Great Lakes in 1856 was only 400 tons, in 1890 it was 2744 tons, and in 1904 it had risen to 10,300 tons, which was carried by the *Augustus B. Wolvin*.

VISIT TO BUFFALO.

The Buffalo Reception Committee consisted of the following gentlemen: Mr. T. Guilford Smith (chairman), Messrs. John J. Albright, Robert S. Beatty, Arthur D. Bissell, James J. H. Brown, Stephen M. Clement, Fred C. Deming, Charles F. Dunbar, W. Caryl Ely, Richard Emory, Gen. George S. Field, George V. Forman, Robert L. Fryer, William H. Glenny, Charles W. Goodyear, Frank H. Goodyear, William H. Gratwick, Gen. Francis V. Greene, Horatio C. Harrower, Edmund Hayes, George B. Hayes, R. R. Hefford, Hugh Kennedy, O. P. Letchworth, Elgood C. Lufkin, F. Howard Mason, Elliott C. McDougal, Eben. O. McNair, George W. Miller, Josiah G. Munro, Richard O'Donnel, Maurice B. Patch, Henry J. Pierce, Ralph H. Plumb, Harry M. Poole, Peter A. Porter, Pascal P. Pratt, George F. Rand, William B. Rankine, George L. Reis, Nathaniel Rochester, William A. Rogers, Edgar B. Stevens, Lucas H. van Allen, and Pendennis White.

The Ladies' Reception Committee included Mrs. John Miller Horton (chairman), Mrs. John J. Albright, Mrs. Arthur D. Bissell, Mrs. J. H. Brown, Mrs. W. Caryl Ely, Mrs. George S. Field, Mrs. George V. Forman, Mrs. Charles W. Goodyear, Mrs Edmund Hayes, Mrs. Ogden P. Letchworth, Mrs. Peter A. Porter, Mrs. George L. Reis, Mrs. Nathaniel Rochester, Mrs. William A. Rogers, Mrs. T. Guilford Smith, and Mrs. Pendennis White.

The programme of arrangements, issued by the Chamber of Commerce, was distributed among the members on arrival. It contained notes of the visits to be made, and a photographic view of the Falls of Niagara, viewed from the American side.

In the evening of November 6 the train arrived at Buffalo, where the members proceeded to the headquarters, the Lafayette Hotel, and subsequently visited the Buffalo and Saturn clubs shortly after their arrival. On Sunday no official visits were arranged. A trip in special cars was, however, made to Niagara Falls, members stopping on the way to inspect the great plant of the Niagara Falls Power Company.

On Monday morning the party was taken by special train to the plant of the Lackawanna Steel Company. Luncheon was served on the train, and in the afternoon the party proceeded to the works of the Buffalo and Susquehanna Iron Company.

Mrs. John Miller Horton, chairman of the Ladies' Committee, invited the lady visitors to a drive round the city, followed by luncheon at the Country Club, and later by a tea and reception at the house of the Twentieth Century Club. In the evening a reception was given at the Ellicott Club. Captain J. J. H. Brown, president of the Chamber of Commerce, was assisted in receiving by Mr. T. Guilford Smith, chairman of the Reception Committee, Mrs. John Miller Horton, and Mrs. J. J. H. Brown. The party left Buffalo for New York on the morning of November 9 by the picturesque Hudson River Line. The special arrangements for this journey were made by Mr. G. F. Baer, and for a portion of the run the train attained a speed of 72 miles an hour. New York was reached on the evening of the Presidential Election, when the popular enthusiasm was at its height.

THE NIAGARA FALLS POWER COMPANY.

On the way to Niagara Falls, on Sunday, November 6, the members stopped at the power-houses of the Niagara Falls Power Company, and inspected the plant and appliances. The works, which have only been in operation nine years, are on a scale of great magnitude. The water from Niagara, by means of which the power is obtained, is taken in by a canal 1250 feet long, and varying from 100 feet to 250 feet in width. This water is drawn in by twenty-one inlets to twenty-one turbines, after operating which it is discharged into the lower river. There are ten 5000 horse-power and eleven 5500 horse-power turbines, installed in two wheel-pits, which the visitors were taken to see, situated 141·5 feet below the power-house. The turbines in No. 1 power-house are of the Fourneyrow twin type, those in power-house No. 2 being of the Francis type, single. The generators are in each case on the upper level, being connected with the turbines by hollow vertical shafts. The generators in No. 1 house are Westinghouse machines; in No. 2 house machines by the General Electric Company have been adopted. The local distributing plant consists of a subway 2155 feet long, with a horse-shoe shaped cross section 3·83 feet by 5·5 feet, and of 38,420 feet of conduit composed of vitrified tile ducts 3½ inches in diameter. These conduits contain 632,000 linear feet of single duct, in which are laid 364,000 feet of lead-covered copper cable, most of the cable having a cross section of 1,000,000 circular mils. The long-distance distributing plant comprises two separate and distinct pole lines carrying three tri-phase transmission circuits. Two circuits consist of copper cable 350,000 circular mils. in cross section, approximately $\frac{7}{10}$ inch in diameter; the third circuit is of aluminium cable having a cross section of 500,000 circular mils. and a diameter of approximately $\frac{8}{10}$ inch. The distance of the overhead transmission line between the power-house and the terminal-house in Buffalo is 22·5 miles. The maximum output of the two power-houses up to date is 75,000 horse-power, of which 30,000 horse-power is delivered in Buffalo, the Tonawandas, and Lockport, and 45,000 horse-power used locally by industries on the Power Company's lands. Output of plant for the year 1903 was 348,372,512 kilowatt hours—approximately 10 per cent. of the aggregate output of all the central electric light and power stations in the United States. To produce this output by steam would require the consumption of 600,000 tons of coal, or 1640 tons daily. The first works to utilise power were the Pittsburg Reduction Company, who have established themselves close by, in immediate proximity with the Castner Alkali Company, from which they obtain the sodium necessary in the manufacture of aluminium. Power-houses are also in course of erection on the Canadian side of the Falls on lines similar to those of the American plants. The plant will consist of eleven generating units of 10,000 horse-power each. By means of interconnecting cables between this Canadian power-house and the two power-houses of the Niagara Falls Power Company, power can be transferred from any of these three allied plants to either or both of the others, so that power users supplied from either will have ample reserve to guarantee continuity of power service.

THE LACKAWANNA STEEL COMPANY.*

The visit to the works of the Lackawanna Steel Company was paid on Monday, November 7, by a party of eighty-eight members. A special train took the visitors to Lackawanna Station, starting at 10 A.M. from Buffalo. It was understood that the works were in an unfinished condition, but this lent additional interest to the visit. It was seen that the difficulties encountered as regards the foundations had been successfully surmounted, while the great natural advantages of the situation, which affords an extensive frontage to the shores of Lake Erie, and the exceptional facilities for obtaining supplies, and for despatching the output by rail were fully appreciated. The train was run into the works over the company's tracks, and the

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* Detailed accounts of these works appear in the *Iron Age*, Jan. 7, 1904, pp. 49–68, and in the *Iron and Coal Trades Review*, June 26 and August 21, 1903.

party alighted at the coke-ovens, and was met by Mr. G. L. Reis, general manager, and Mr. F. B. Sheldon, general superintendent.

The members first proceeded to inspect the coke plant, which is on a large scale. The systems employed are Otto-Hoffmann and Rothberg. There are 550 ovens, arranged in batteries of 50, here, with 400 more projected; at the mines there are 500 more. The present output is 4000 tons of coke per diem.

The members then proceeded to the furnaces, 90 feet high, 13-foot boshes, with twenty to twenty-two tuyeres, and thence to the power-houses, where there is an interesting air-compressor with Corliss valves, built by the Nordberg Manufacturing Company, of Milwaukee, and on to the Cochrane feed-water plant, where the boiler feed is purified in tanks. Lackawanna is the only works in America at which a blast-furnace gas power plant has, up to the present, been adopted. When completed, it will be the largest power gas plant in the world. There are eight Koerting engines, and a 1000 horse-power Porter-Allen engine in power-house No. 1, while in power-house No. 2, eight large gas blowing-engines and a double-cylinder Koerting gas-engine of 2000 horse-power have been installed.

The members then went to the new universal 42-inch continuous plate-mill. This has three sets of rolls, arranged on the Morgan principle, two sets perpendicular and one set horizontal, with a tremendous train of live roller-gear, built by the Morgan Engineering Company, of Alliance, Ohio. The soaking-pits and the new 32-inch universal slabbing-mill, a huge mill of the reversing type, built by Macintosh, Hemphill, & Company, of Pittsburg, and intended to roll ingots up to 54 inches wide and 30 inches thick, was next visited. The horizontal rolls are driven by a 46-inch by 60-inch two-cylinder reversing engine, and the vertical rolls by a 36-inch by 48-inch engine of the same type. The total weight of this portion of the plant is 2100 tons. The mill, which was designed by Mr. Julian Kennedy, was put into operation for the first time on the day of the visit.

From the steel and slab mills the members went to the soaking-pits, and then to the smelting department, where there are six 60-ton basic open-hearth furnaces, after viewing which they were taken to the canal, which is 200 feet wide, 22 feet deep, and has dock frontage 2000 feet long. The great cantilever cranes and ore-handling appliances were inspected, after which the party left by train for Susquehanna.

The plant when completed will consist of three blast-furnaces

87 feet by 17 feet, each furnished with central combustion Chaman stoves, with an annual capacity of 415,000 tons of pig iron, and three blast-furnaces 94 feet by 24 feet, with a capacity of 720,000 tons, the stoves for these three furnaces being 22 feet by 121 feet. The total annual output will thus amount to 1,135,000 tons of pig. The Bessemer department consists of four 10-ton converters and eight iron and four spiegel cupolas, the annual production of ingots being 845,000 tons. The No. 1 rail mill has six 16-hole heating-pits, and five stands of 32-inch rolls, being capable of turning out 600,000 tons of steel rails per annum. The No. 2 rail mill contains five continuous heating furnaces and five stands of 24-inch rolls, the estimated output of miscellaneous sections being 190,000 tons. The open-hearth department contains six 60-ton basic furnaces. There is a universal 48-inch mill, annual output 180,000 tons; a 32-inch slabbing-mill, annual output 240,000 tons; and a merchant mill, 16-inch and 12-inch combination, to turn out 75,000 tons; the total capacity of the works aggregating 1,095,000 tons of ingots and castings, 240,000 tons of slabs, blooms, and billets, 670,000 tons of standard and light rails, and 375,000 tons of other finished rolled products. The company also possesses 940 ovens, and, when the coke plant is completed, will have an annual capacity of 1,198,000 tons of coke.

The Buffalo and Susquehanna Iron Company.

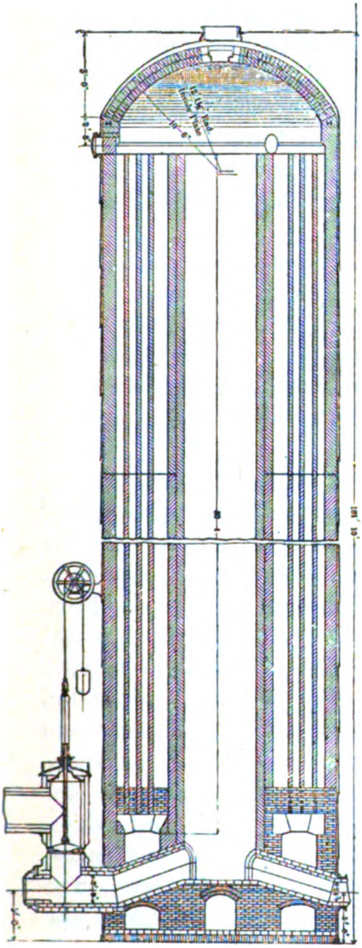
The visit to the Susquehanna furnaces, made on the afternoon of November 7, proved one of the most instructive, from the point of view of American blast-furnace practice, paid during the tour. The ore, fuel, and fluxes are taken by means of an elevated railroad over a double system of bins, one set for each furnace. From these bins the materials are delivered automatically into electric lorries, which run underneath, and receive weighed quantities, which are subsequently hoisted on an endless chain to the furnace-tops and charged. The bell is controlled from a lever room in each house, and a pointer indicates the arrival of the charged lorry at the top, whereupon the bell is depressed and the burden dumped in the usual way. Two men only are required to attend to the entire charging of a furnace, one operating the bell and the other the lorry. After viewing these arrangements the visitors proceeded to inspect the furnaces themselves. The following particulars were furnished by the company in an illustrated pamphlet presented to the members.

The plant is connected with the harbour at Buffalo by a canal about 4000 feet long, and upon completion ore steamers will be able to come direct to the Iron Company's docks. Buffalo was selected as the location of the plant because it is one of the best points in the United States for the economical assembling of the raw materials required in the manufacture of iron, and because, when made, the pig iron is in the midst of a large market which is at present incompletely supplied by local furnaces.

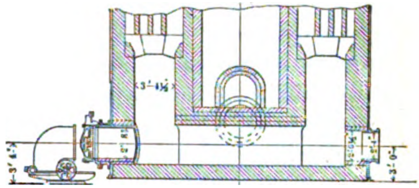
The Buffalo and Susquehanna Iron Company is one of the few independent companies that control their own iron ore and coal supplies. The company even controls the transportation of its raw materials, in that these will be carried by closely affiliated corporations. Thus the iron ore will be brought down the Great Lakes by a line of steamers, of which the *Frank H. Goodyear* is the pioneer, and the coke will be brought direct to the furnaces from the coalfields of Pennsylvania by the Buffalo and Susquehanna Railway Company. The ore properties of the Iron Company are situated at Iron Mountain, Michigan, in the Menominee Range, and at Hibbing, Minnesota, in the Mesabi Range. Each property covers eighty acres of land. Although the exploration of the latter property is not as yet complete, 26,000,000 tons of ore have already been located. The ore obtained from the former property is coarse, and is suitable to mix with the finer ore obtained from the latter. The coal supply is obtained from Tyler, Pennsylvania, and Sykesville, Pennsylvania, in the Reynoldsville Basin. The coalfields cover 3945 acres, and are underlaid with upwards of 25,000,000 tons of excellent coking and steam coal. The Tyler property is now producing at the rate of about 200,000 tons per annum, while at Sykesville the main shaft has reached the coal-seam, and the boilers, hoisting machinery, and plant in general are being rapidly erected. Six hundred coke-ovens are now in process of erection. It is expected that shipments of coke will begin at an early date.

The plant at Buffalo consists of two blast-furnaces and the necessary stoves, blowing-engines, pumps, cranes, &c. The casting-beds are at each end of the plant, and between them are the furnaces, stoves, stacks, and boiler-house. By this arrangement the railroad tracks, which run on each side of the casting-beds, are close together, and take up a minimum amount of yard room.

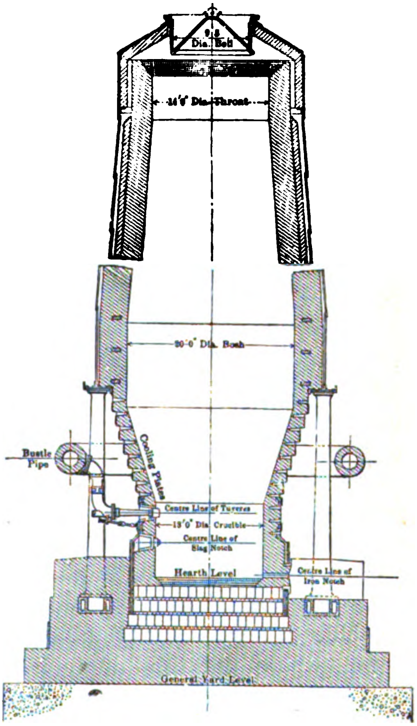
The furnaces are 80 feet high, 14 feet at the throat, 20 feet at the bosh, and 13 feet at the crucible. (See Figures.) These dimensions were chosen as being most satisfactory for the manufacture of foundry iron, which the company produce. The make is from 600 to 700 tons of foundry pig iron per day, or about 225,000 tons per year. Each furnace is equipped with four fire-brick stoves and one stack. The stoves



SECTION THROUGH HOT-BLAST VALVE AND GAS-BURNER.



SECTION THROUGH CHIMNEY AND COLD BLAST VALVES



SECTION OF BLAST-FURNACE.

are 102 feet in height and 22 feet in diameter. They have central combustion chambers, and are of the Julian Kennedy type. The stacks are 175 feet high and 12 feet diameter, and are lined with fire-brick. The engine-house, which contains the blowing-engines, pumps, and electrical machinery, is 204 feet long by 88 feet wide. The blowing-engines are four in number, and of the cross compound vertical steeple type. They were built by the Allis-Chalmers Company of Milwaukee. They are of 2000 horse-power each, or 8000 horse-power in all. The pumping plant consists of three large compound cold-water pumps, built by the Snow Steam Pump Works of Buffalo, New York, three compound feed-pumps for the boilers, and an air-pump for the condenser.

The boilers, which are twenty-four in number, are arranged in twelve batteries in a building 364 feet long by 41½ feet wide. They have a total of 6000 boiler horse-power, and are of the Cahall horizontal type, built by the Aultmann and Taylor Machinery Company of Mansfield, Ohio, and fired by waste gases, but there is a small coal grate which can be used when the furnace gases are not sufficient to keep up steam.

When the canal is completed the vessels which bring the ore and the limestone will come in from the harbour to the company's wharves, and unload either into the ore storage piles, or directly into the ore bins. The raw materials will be taken from the vessels by automatic machinery, and carried by overhead bridges to the stockyard. From there they will be picked up by grab buckets, and deposited in the bins. The latter are in a double row, so that coke and ore may be loaded in them at the same time. The coke is brought in 50-ton automatic dump cars by the Buffalo and Susquehanna Railway, and emptied directly into the bins. Pending completion of the above road, the coke is being brought in over another line. From the bins the raw materials are taken by electric cars and emptied into skips, which, in turn, take them up the inclined skipways to the furnace-top, where they are dumped automatically in the furnaces. The hoisting engines are on the opposite side of the furnaces from the skipways, and the ropes run over the top of the furnaces. This takes away the engines from over the skip pit, and makes the steam connection shorter than usual. By this general arrangement of the plant the materials are handled most economically. While navigation on the lakes is open the ore can be unloaded directly into the bins, and the rehandling necessary at practically all other plants saved.

Similarly, the coke can be emptied into the bins without rehandling. Furthermore, the railroad tracks run on both sides of the cast-houses, so there need be no rehandling of the pigs at that point.

The plant was arranged by Mr. Julian Kennedy in conjunction with Mr. Wm. A. Rogers, president of the company, and Mr. Hugh Kennedy, general manager of the company.

The members reached No. 1 furnace a few minutes before tapping, while the slag was being run off and granulated. There is a pig-breaker of the hydraulic type. The pig-beds are moulded by hand, one comb of pigs being moulded at a time, by means of a wooden pattern of the pigs and channel, which is laid on the bed, and stamped down, after which it is lifted clear by means of a small crane.

VISIT TO SCHENECTADY.

A party of members of the Institute left the main party at Albany, under the guidance of Mr. E. H. Mullin, in order to visit the works of the General Electric Company.* The night was spent at the Ten Eyck Hotel at Albany, and during the evening great interest was taken in awaiting the election results, and also in watching the excited crowds which thronged the streets. The next morning a start was made at 9.45, a special chair-car provided by the General Electric Co. being in readiness opposite the hotel to convey the party some seventeen miles to Schenectady. The run was a delightful one, and although at times the car attained a speed of from forty to fifty miles an hour the smoothness of running was particularly commented upon.

The party was received at the office of the company by Mr. Emmon (general superintendent) and other members of the staff. The ladies were entertained at the Golf Club by Mrs. and Miss Darling whilst the members inspected the works. The party first visited the railway motor-shop, where numerous motors of all sizes suitable for railway and tramway work are manufactured. Special horizontal boring-machines for facing the ends and pole-pieces of the outer casting of the motors were particularly noticeable. The party were next conducted to the big machine-shop, where large dynamos and motors for both direct and alternate current work were seen in course of construction. The whole of one end of this shop is occupied by a large bed-plate, upon which the large castings are set and then

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* This report has been prepared from notes kindly furnished by Mr. J. C. W. Humfrey, M.Sc., Member of the Iron and Steel Institute.

operated upon by means of machine-tools movable over the bed-plate. The party spent some time in examining a large boring-mill capable of taking work up to 60 feet in diameter. Along one bay of this shop all machines are tested before leaving the works, being afterwards carried by means of a continuous overhead crane to a building on the opposite side of the main road through the works, where they are painted and shipped. The lighting of this and most of the other shops visited is carried out by means of translucent skylights of wire gauze treated with linseed oil, this material having been found to give a far more pleasant working light than glass.

The next shop visited was particularly interesting, the party having the opportunity of seeing the complete manufacture of the Curtis turbine. These machines are now being largely installed for electric light and power plants, their great advantages in minimising not only floor space and foundations, but also steam consumption, making them serious rivals to the ordinary steam-engine. The turbine works entirely on the reaction and not on the impulse principle; the steam expands through blades fixed to the periphery of discs on the revolving shaft, entering from nozzles on the outer casting. The governing is regulated by the number of these nozzles open for the admission of steam. In the large machines the blades are cast in brass segments containing about a dozen, these being trued up by special tools and fastened to the disc; in the smaller machines, however, they are cut from the solid cast-steel disc by most interesting tools which accomplish the whole process in one operation. Several turbo-generating sets — one of 3000 kilowatts — were undergoing tests in this shop. On an upper floor were some special machines for bending copper strip into continuous spirals for field-magnet coils.

The party then crossed to the power-house. The power is obtained from horizontal engines, turbines, and rotary converters. The latter are supplied, by means of step-down transformers, with three-phase alternating current transmitted at 30,000 volts from a water-power station on the Upper Hudson, and convert it to 250 volts direct current for use in the works. The department for stamping and annealing sheet steel for building up the cores of armatures and transformers was next visited, and the immense output of the company was evident from the fact that about 1300 tons of sheet pass through this shop per month. The annealing furnaces (using producer-gas) are worked in a most exact manner, the temperature being regulated by means of pyrometers passing down into the pots at various places in the furnace.

The party were then taken back to the office buildings, where luncheon was provided. At its conclusion Mr. T. Westgarth thanked the company on behalf of the Institute for the liberal manner in which they had thrown open the works for their inspection. Mr. Emmon replied on behalf of the company. After luncheon a move was made to the foundry. This is one of the largest in the country, and contains one of the largest cupolas—84 inches diameter. The entire work is carefully supervised by means of analysis, all castings being of a special exact composition for the purpose required. Castings of all sizes, from the huge frame of a 5000-kilowatt generator to small machine-moulded fittings, are produced, and this shop was perhaps of chief interest to many of the visitors. The party next visited the new power-house, at present not fully completed. This plant, which is to be entirely driven by Curtis turbines, will eventually supplant the one previously visited. The cable and insulated wire department was entered next, and the weaving, insulating, and sheathing both of large cables and of small wires for house-wiring were seen in operation. From here the party passed to the porcelain works, and witnessed the manufacture of all kinds of lamp and switch fittings. On the way to the transformer-house, which completed the tour of the works, a large new machine-shop, at present in course of construction, was inspected, and the foundations for numerous big machine-tools seen. At about four o'clock the party left the works by special car, and proceeded by train to New York.

THE ST. LOUIS AND CHICAGO EXCURSION.*

At Pittsburg, on November 3, the members separated into two parties. The St. Louis party, which numbered 75, were soon installed in the special train provided, which consisted of baggage-van, a combination-car, a dining-car, two state-room cars, an ordinary Pulman car, and at the end an observation-car. Besides sleeping, feeding, and living accommodation, there were writing facilities, a barber's shop, and a bath-room. The excursion was under the general direction of Mr. A. Ladd Colby.

The trip was almost an ideal one, no serious complaint being heard from the start on November 3 until the train was forsaken

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* This report has been furnished by Mr. D. A. Louis, who acted as Institute Secretary during this excursion.

finally on November 12. This is saying very much for the excellence of the arrangements and commissariat, for it must be remembered that a party exceeding seventy in number, slept, lived, and fed in the train for the greater part of a period of more than eight days.

The first morning there was a general consensus of opinion concerning the great comfort of the night. The State of Ohio had been traversed during the night, Indianapolis (Indiana) was passed at 7 A.M., and the State of Illinois entered a couple of hours later. The open farmland, with a fair sprinkling of trees, hitherto encountered, was now diversified by an occasional small colliery. At Greenville a delegation from the St. Louis Reception Committee arrived, consisting of Messrs. Arthur Thacher, Herbert A. Wheeler, H. E. Flewellin, H. A. Johann, and F. B. Laney.

Soon the train crossed the Mississippi, entering simultaneously the State of Missouri and the city of St. Louis, before two o'clock on Friday, November 4. The train was driven, by the courtesy of Mr. J. Ramsay, President of the Wabash system, to a siding just outside the main entrance to the Exhibition, and the visitors were taken in hand at once by the members of the Reception Committee, and were given a grand automobile tour round the Exhibition grounds. The drive terminated at the building of Mines and Metallurgy, where Dr. Holmes (Chief of the Department of Mines and Metallurgy) delivered an address of welcome, to which Mr. William Whitwell (Past-President) replied. A programme was distributed on arrival, containing time-tables of the various functions, and a list of the Local Committee. After light refreshments, electric launches in waiting on the lagoon were boarded, and a most delightful tour of the waterways was made, which enabled the visitors to enjoy and appreciate the extensive and beautiful illuminations. A return was made to the train for dinner, but later on the automobiles were again in attendance to take the visitors to a reception given by the World's Fair officials. The automobiles were, in fact, in attendance each day, and they alone made it possible for the visitors to see as much as they did of the Exhibition in the time at their disposal. On November 5, the boiler-house, the machinery building, the electricity building, the transportation building, and some of the sights were inspected, the evening being reserved for the Pike, where the revelries of a fair on a colossal and gorgeous scale could be studied. On November 6 (Sunday), by special courtesy of the Exhibition authorities, the visitors were enabled to make a private inspection of the mining and metallurgical exhibits, which they appreciated highly, and found Mr. Bauerman's paper of great value as a guide. They were also taken an automobile drive through the city, and entertained on board the house-boat, *The Everglades*, on the Mississippi, by the Reception Committee and Colonel and Mrs. Robert M. Thomson, of New York. Monday, November 7, was devoted to visiting more of the Exhibition, including the United States Government exhibits and the interesting and complete coal-testing plant. In the afternoon Dr. W. P. Wilson, Chairman of the Philippine Commission, conducted the visitors through the Philippine encampments. Tea was provided in the Ceylon building, followed by dinner on the train and a farewell reception by the Local Committee in the American section of the Fine Art building, which brought the visit to the St. Louis Exhibition to a close.

St. Louis was left at 11 P.M., and Chicago was reached at 8.30 A.M. on November 8. On the way a programme and an excellent guide to Chicago were distributed by Mr. A. W. Fiero, of the Chicago General Committee, who had come to St. Louis for the purpose. The approach to Chicago, the view over Lake Michigan, the remnants of the great Chicago Exhibition in Jackson Park, and the reclamation operations on the shore attracted attention. At Chicago the visitors left the train, and were all accommodated in the Auditorium Annex, where also were the headquarters office in charge of Mr. Warder. Shortly after arrival the party were taken through the Illinois Telephone Company's railway tunnel by Mr. George W. Jackson, chief engineer. They then went to the Art Institution, and on to the retail store of Marshall, Field, & Company, the largest establishment of its kind in the world, where a dainty luncheon was provided. Some then proceeded to the stockyards, some to the Griffin Car-wheel Works, and some took a trip on the Chicago River in a tug, well provisioned, for although the river is short the journey may be prolonged owing to the numerous bridges which stop progress. The object was to see the Fisk Street station of the Commonwealth Electric Company (where Messrs. Samuel Insull, president, L. A. Ferguson, superintendent, and W. L. Abbott, vice-president, received the members), and the McCormick Works of the International Harvester Company, in charge of the general manager, Mr. A. E. S. Clarke. In the evening the party were the guests of the Local Committee at the Studebaker Theatre, and subsequently at a characteristic after-theatre champagne supper, where some cordial words of welcome from Mr. Robert W. Hunt, Chairman of the Chicago Executive Committee, were acknowledged by Sir Walter Foster, M.P. At the theatre, between the acts of the play, the returns of the voting for the Presidential elections were announced, and received with enthusiastic outbursts of applause. A party under the leadership of Mr. Morgan visited the Grand Crossings continuous wire-rod and continuous billet mills. On November 9 the ladies were taken in automobiles to see the parks and boulevards, of which Chicago is justly proud, the complete round making a journey of 40 miles, and the rest of the party went by special train to the South Works of the Illinois Steel Company, with which they were deeply impressed. The members were entertained at luncheon by the Company, who also presented tasteful badges as souvenirs of the occasion. In the absence of Mr. E. F. Buffington, the president, the chair at the luncheon was taken by Mr. Theodore W. Robinson, vice-president, and in welcoming the members he expressed his appreciation of the international character of the Institute. Mr. Bauerman, Dr. A. Weiskopf, and Mr. Jules Magery replied on behalf of the Institute.

Returning to Chicago, the visitors bade adieu to their hosts, rejoined the special train, and left at 6 P.M. for Niagara, which was reached at eight o'clock the next morning. Here the party soon dispersed on their own account, visiting the Falls and various works in the district. At five o'clock a start was made for Buffalo, when they again detrained, and were accommodated at the Lafayette Hotel, and after dinner a pleasant evening was spent at the Buffalo Club. The next day a visit was paid to the Lackawanna Steel Company's plant and to the Buffalo and Susquehanna Iron Company's blast-furnaces.

Shortly after the arrival at the Lafayette Hotel the services of the staff were suitably acknowledged, Mr. W. Whitwell, on behalf of the members of the party, presenting Mr. Vaughan with a gold watch, Mr. Clyde with a silver bread-basket, and Mr. Reynolds with a silver cigarette-case, as tokens of the appreciation of the good services rendered in their respective departments throughout the excursion. Buffalo was left at 6 P.M., when the comfortable special train started on the final stretch over the New York Central and Hudson River Railroad to New York, which was reached at 5 A.M., thus terminating one of the most successful excursions in which the members of the Institute have ever had the privilege to take part.

The names of the members of the Reception Committees at St. Louis and at Chicago are appended. The Executive Committee of the

St. Louis Committee comprised Messrs. Arthur Thacher, Chairman (President Central Lead Co.); Herbert A. Wheeler, Secretary and Treasurer (Mining Engineer); Joseph A. Holmes (Chief Department Mines and Metallurgy, World's Fair); Pierre Chouteau (Vice-President St. Louis World's Fair); P. N. Moore (Mining Engineer); F. E. Drake (President Lanyon Zinc Co.); H. E. Flewellin (International Nickel Co.); H. C. Meister (Manager Collinsville Zinc Co.); B. F. Bush (Manager Western Coal Co.); E. W. Parker (Manager U. S. Coal-Testing Plant, World's Fair); and J. C. Robinson (Manager St. Louis Portland Cement Co.).

The General Committee comprised: Messrs. W. E. Goldsborough (Chief Department of Electricity, World's Fair); Cloyd Marshall (Assistant Chief Department of Electricity, World's Fair); T. M. Moore (Chief Machinery Department, World's Fair); C. K. Mallory (Superintendent Machinery Department, World's Fair); W. A. Smith (Chief Transportation Department, World's Fair); Percy Hudson (Superintendent Transportation Department, World's Fair); H. C. Ives (Chief Art Department, World's Fair); C. M. Kurtz (Assistant Chief Art Department, World's Fair); V. C. Heiks (Assistant Chief Department Mines and Metallurgy, World's Fair); W. S. Ward (Department Mines and Metallurgy, World's Fair); W. H. Reeves (St. Louis Manager Worthington Hydraulic Co.); W. B. Potter (Mining Engineer); E. R. Buckley (Missouri State Geologist); R. A. B. Walsh (Manager Mississippi Glass Co.); W. T. Totten (St. Louis Agent Carnegie Steel Co.); S. A. Goodrich (St. Louis Agent Jones & Laughlin Steel Co.); H. P. Hubbell (St. Louis Agent Cambria Steel Co.); J. G. Miller (St. Louis Agent Pennsylvania Steel Co.); F. B. Sharp (St. Louis Agent Worth Brothers Steel Co.); J. C. Davis (Manager American Steel Foundry Co.); J. K. Hoblitzelle (Secretary American Steel Foundry Co.); J. V. Bell (American Steel Foundry Co.); C. H. Howard President Commonwealth Steel Co.); W. E. Guy (President Madison, Coal Co.); Wm. Chauvenet (Chemist); E. L. Foote (Manager Sligo Iron Co.); J. T. Monell (Superintendent Central Lead Co.); A. R. Meyer (Manager Kansas City Smelting Works); E. S. Gatch (Manager Granby Zinc Mining and Smelting Co.); Edwin Harrison (Mining); Arthur Bonsack (St. Louis Agent Ingersoll Drill Co.); J. A. Prescott (St. Louis Agent Rand Drill Co.); H. A. Johann (St. Louis Agent Taylor Iron Co.); F. B. de Camp (Manager Missouri Furnace Co.); T. B. Fogg (Missouri Pacific R. R.); Richard McCullough (Manager St. Louis Transit Co.); Joseph Hyde Pratt (Mining Engineer); F. B. Laney (Geologist); G. Sessinghaus (Mining); R. L. Humphreys (Civil Engineer); and Robert Aull (Park Commissioner of St. Louis).

The Reception Committee of the St. Louis Engineers' Club comprised: Messrs. J. A. Ockerson, President (Civil Engineer); Robert Moore, Vice-President (Civil Engineer); R. H. Fernald, Secretary (Mechanical Engineer); E. E. Wall, Treasurer (Civil Engineer); S. B. Russell, Chairman (Civil Engineer); Wm. H. Bryan (Mechanical Engineer); A. S. Langsdorf (Electrical Engineer); C. A. Moreno (Civil Engineer); and H. A. Wheeler (Mining Engineer).

The Chicago Reception Committee comprised: Executive Committee: Messrs. Robt. W. Hunt (chairman), T. W. Robinson, R. Forsyth, F. C. Baackes, T. A. Griffin, G. R. Johnson, E. C. Potter.

General Committee: Robt. W. Hunt (chairman), T. W. Robinson, E. A. S. Clarke, W. J. Chalmers, E. J. Buffington, Samuel Insull, Harold McCormick, Wm. L. Brown, Wm. L. Abbott, T. A. Griffin, Louis Mohr, T. J. Hyman, Richard Howe, E. L. Ryerson, C. P. Wheeler, W. R. Stirling, John Crerar, F. C. Baackes, A. M. Thompson, W. N. Coleman, Geo. W. French, John S. Keefe, E. C. Lott, John G. Shedd, Alex. B. Scully, R. Forsyth, C. H. McCullough, John K. MacKenzie, August Ziesing, R. T. Crane, Jun., E. A. Turner, H. G. Johnson, F. K. Copeland, F. A. Delano, C. H. Ferry, A. W. Fiero, F. H. Foote, H. L. Hollis, Wm. Hoskins, Geo. Merryweather, Geo. S. Rice, Rudolph Ortman, W. A. Field, C. T. Boynton, Prentice Coonley, E. P. Bailey, and E. C. Potter (secretary).

Ladies' Committee: Mrs. R. W. Hunt (chairman), Mrs. J. K. MacKenzie, Mrs. E. L. Ryerson, Mrs. E. C. Potter, Mrs. John Crerar, Mrs. W. G. Pierce, Mrs. J. F. Stevens, and Mrs. Alexander Finn.

During the stay in Chicago, the Board of Directors of the Western Society of Engineers extended the courtesies of the Society to the members.

THE ST. LOUIS EXHIBITION.

The mining and metallurgical exhibits have been described in the paper by Mr. H. Bauerman, who, as well as members of the Local Reception Committee, was in attendance to facilitate inspection for the visitors. Special badges were presented to the members, and Mr. A. L. Colby, on behalf of the International Nickel Company, distributed malleable-nickel medals. In order to save time luncheon was kindly provided each day at some convenient place in the Exhibition by the Local Committee.

THE ILLINOIS TUNNEL COMPANY'S TUNNELS.

As the result of four years' work twenty miles of tunnels now underlie Chicago 24½ feet from the surface. Nearer the surface all space is already occupied. These tunnels were originally intended for the wires of the Illinois Telephone and Telegraph Company, for which purpose £1,000,000 was subscribed; later, under the auspices of the Illinois Tunnel Company, with a capital of £12,000,000, they developed into providing accommodation for postal and goods as well as a telephone service. They consist of trunk tunnels 12 feet 9 inches by 14 feet high, and lateral tunnels 6 feet by 7 feet 6 inches high, lined with a plaster coating of sand and cement in equal proportions, and provided with a 2-foot gauge track. To construct these tunnels, manholes were not allowed in the streets; therefore eight basements of buildings situated at selected parts of the city were leased, and operations conducted from them through shafts sunk to the blue clay. The pneumatic system of tunnel-driving was employed, and progressed incessantly with three shifts of men, 850 being employed underground, and 600 elsewhere. The excavated material, all drawn up the shafts, was much of it carted to the lake front, and deposited there to become the foundation of park extensions, the rest was taken by barges and dropped in the lake. In construction, after the removal of the blue clay a concrete bottom was carefully laid, and lagging placed on it. Iron ribs of 3-inch channel bar (5-inch in the trunk tunnels) were placed 3 feet apart on the bottom, and extended up the sides and over the top; behind these lagging of 2-inch plank (No. 12 steel in the trunk lines) was adjusted, and the space all round closely packed with concrete. The walls of the lateral tunnels are constructed with 13-inch bottoms and 10-inch sides, those of the trunk tunnels with 21-inch bottoms and 18-inch sides.

MARSHALL, FIELD, & CO.

The magnitude of this great retail establishment may best be gathered from the fact that there is over 1,000,000 square feet, or 25 acres, of floor area; that besides staircases there are fifty lifts; that frequently 100,000 visitors come to the store in a single day; and that the refreshment rooms for the public can seat 2000. There are writing rooms, a library, emergency hospital, sitting rooms, branch post-office, &c.; and there are forty-five large show windows on the street.

The Grand Crossings Continuous Wire-rod Mill.

This mill is situated at South Chicago, and, as so frequently happens, was approached on the present occasion from the wrong end. The first thing encountered was a special form of truck into which coils of No. 5 wire rod were falling from the end of an incline up which they were being pushed in a continuous procession by moving projecting prongs. At the lower end of the incline were two stationary laying reels, each with a revolving hollow radial arm supported in a frame above, and down the centre of this arm hot wire rod was directed by a guide. It passed downwards, and was coiled on the stationary reels; but when a length was finished the guide was moved to the other reel, and the bottom of the full reel was depressed and allowed the coil to fall on the incline, where it was caught by the creeping projecting prongs and taken away. The hot wire rope emerged from a tubular guide extending from the last of the eight finishing rolls. Through this guide water was running to cool the rod out of contact with the air, and so prevent oxidation. The eight finishing rolls were arranged tandem fashion, and the rod made the eight passes automatically through them. The rolls were grooved so that a fresh piece of work was directed into an unoccupied line of grooves on the finishing passes. A gap between the finishing train and the roughing train provided accommodation for the guide for directing the bar into its groove, and for shears to crop the ½-inch square bar as it emerged from the roughing train so as to present always a clear entering end. The roughing train consisted of six stands of rolls also arranged tandem fashion, and separated alternately by straight and twisted guides; the bar obtained in this way the necessary pressure on each side. The first stand of the roughing train abutted on the discharge door of the heating furnace, from which emerged the hot 1¾-inch square billets, which followed one another with only a foot or so interval between the newcomer and its predecessor. So as to keep the mill clear the rolls were running at successively increasing speeds, and the rod left the mill at a speed of about 2000 feet a minute. The passage of a 30 feet 1¾-inch square billet, weighing 300 lbs., through the fourteen passes when it emerged as No. 5 rod occupied less than twenty seconds.

The furnace and accessories are important factors. The furnace bed measured 32 by 20 feet, and sloped 2 inches in a foot towards the lower or discharge end, where it was lined with magnesite brick, the middle portion with fire-brick, while the upper portion was provided with cooled skids; a suspended arched roof directed the heat properly, and served other purposes. The furnace accommodated 130 billets; they were charged in at the top by placing the end between adjustable pinching rollers, and were pushed out below by similar rollers and a square pushing bar, and they were moved down the furnace by a pushing machine at the upper end. The furnace was heated by gas from Morgan producers, and air heated by passing between the arched roof and the upper covering of the furnace. There were fourteen gas jets and an equal number of air inlets, each adjustable. The whole sets of rolls were driven by a 1000 horse-power engine; the roughing train by direct gearing from the engine; the finishing train by two leather belts, one riding on top of the other; each belt driving two pulleys, and each pulley, by a nest of cylindrical gears, two stands of rolls. In the actual mill there were two men and a boy; one man stood at the head, and directed the billet into the mill; the boy looked after the shearing and directing the ½-inch square rod into the first finishing rolls, the other man looked after the rolls. A breakdown occurred during the visit; the boy worked the shears, and ran off with the square rod from the roughing train. The first man stopped the supply of billets; the second man cleared the finishing train, and adjusted matters; within a minute all was at work again. The producers were also inspected. Some were fitted with the revolving spout feed. The Bildt producer was also in use.

THE FISK STREET STATION OF THE COMMONWEALTH ELECTRIC COMPANY.

This building is of agreeable design in red pressed brick, with cut stone trimmings, and large arched windows which give excellent illumination inside. It is situated on the south branch of the Chicago river, and contained at the time of the visit three units of 5000 kilowatts each, with space for an additional unit. The special feature was that the turbo-generators were of the two-stage Curtis vertical type. In exterior dimensions each turbine unit is 29 feet high, 16½ feet in diameter, and weighs about 205 short tons, the weight of the revolving portion being about 70 short tons. Each generator has internal revolving field, six-poles, and runs at a speed of 500 revolutions a minute, the current generated being three-phase twenty-five cycle at 9000 volts. There are various accessories to each generator as well as eight boilers to each unit set at right angles to the line of generators. They are water-tube boilers, with 5000 square feet heating surface and chain grate stokers. The boiler pressure is 180 lbs., with 150 degrees of super-heat. Coal is delivered to bunkers above the boilers by the same conveyor that takes away the ashes. There is a switch-house in which are the switches, exciters, transformers, and recording instruments on one floor, and on the lower floor the bus bars, all high-tension connections and instrument transformers. The whole plant and buildings were in admirable condition. The station is designed to contain 14 turbo-generators.

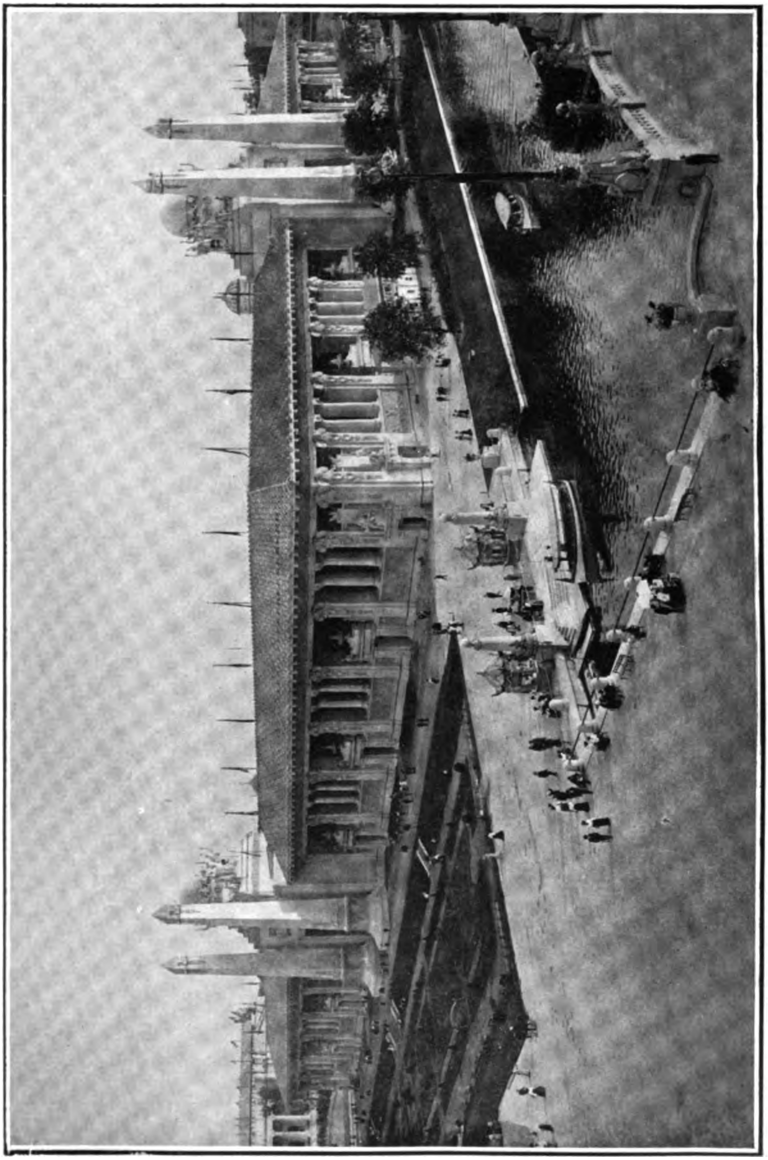
THE INTERNATIONAL HARVESTER COMPANY.

The McCormick works cover 170 acres; 41,000,000 feet of timber are used annually, and between 45,000,000 and 50,000,000 feet are carried in stock; the latter fact was more or less realised by the visitors who passed through the timber yards, and visited the works where the timber was used, where there was a splendid array of wood-working machinery, and where painting and varnishing is done by dipping. The foundry was next visited. It had an open-hearth malleable iron furnace; unfortunately no run could be seen, as the moulding operations were not complete, but by the evening light there seemed to be thousands of moulds spread over the floors ready to be filled. The daily capacity of the foundries is 400 tons of castings, and in 1903, 56,000 tons of pig iron and 57,000 tons of steel were worked up. The whole plant is driven by engines developing 6912 horse-power, and at times 90 to 100 cars of machines are shipped a day; in fact, complete machines of one kind or another are turned out at the rate of one every twenty-four seconds. The Company owns other works besides the McCormick works.

ILLINOIS STEEL COMPANY'S SOUTH WORKS.

The Illinois Steel Company is part of the Federated Steel Company which is associated with the United States Steel Corporation. The South Works of the Illinois Company cover 330 acres, have ten blast-furnaces, an open-hearth plant at work and one in construction, a slabbing-mill, a rail-mill, a plate-mill, Bessemer works, foundries, repair shops, cement works, and a steel mill nearing completion with an annual capacity of 270,000 tons of blooms. On the occasion of the visit, the special from Chicago drew up in front of the new open-hearth works, and the grand proportions, the spacious and well-laid floor, soon caught the eye. In this works, which is 550 feet long and 60 feet wide, seven 50-ton open-hearth furnaces were being installed and equipped upon the newest lines. The range of producers runs parallel with this steelworks; four are allotted to each furnace. They were provided with the revolving spout-feeding arrangement which now seems in favour in America, and has distinct advantages over its prototype, Bildt's, particularly noticeable in the external gearing. The capacity of these furnaces will be 250,000 tons of ingots. A train of decorated trucks awaited the visitors, who were conveyed to a splendid battery of ten blast-furnaces exhibiting many attractive features, but time did not permit of close inspection Immediately behind these furnaces the great ore store, consisting of enormous pens, where ore has to be stored to supply the furnaces during the winter, when ore cannot be shipped from the mines; for Lake ore is used, with about 57·6 per cent. of iron. The ore pens are served by two travelling steel bridges, each 600 feet in length, and running on two pier walls 190 feet apart, and these, by means of a 10-ton grab-bucket and one man on each bridge, distribute the ore from the discharge-trough about the storage-pens or from the latter to the charging bins at the blast-furnaces. The discharge-trough is V-shaped, runs the whole length in front of the storage-pens, and receives its charge from the unloader. The unloader is two groups of adjustable aprons mounted upon travellers, which move along the dock to serve the steamers. Each apron has a 5-ton grab, which is lowered into the steamer and transfers the ore to the V-shaped trough. These appliances were seen in operation, and from here the skip-hoists of the blast-furnaces could be observed in the distance. It was stated that 2,000,000 short tons of ore were in the pens at the time of the visit. Away the party went in the train of trucks, past the blast-furnaces, to the engine-house, to see a noble display of seventeen blowing-engines for use in six of the furnaces. Five horizontal cross-compound engines and twelve vertical, two of which were of the Allis cross-compound steeple type recently started, and expected to blow 30 lbs. at 40 R.P.M. Thence the Bessemer works were visited. Here were two 150-ton mixers and three 15-ton Bessemers, side by side, as busy as busy could be, producing a grand effect pyrotechnically and otherwise, for during the visit two heats were poured and a third was nearly ready; in fact, 160 heats a day are taken. The metal is poured into a receiver, and thence transferred with the distributing-ladles. Two trains of ingot-cars are charged at the same time, and as soon as a full one is off an empty train takes its place and is receiving its charge. On the way to the soaking-pits the trains pass through the stripping-shed, and two ingots at a time are stripped. The rail- or section-mill was next visited, with one three-high blooming and one three-high finishing train and four stands of rolls, and the rapid progress of the work through it was followed with interest, being cogged, roughed, and finished in the same mill, passing along on live-rolls, to be roughed and swung up by tilting-arms to the finishing train alongside. A scene of incessant movement, the output of this mill is 1500 tons of section steel per day. The old open-hearth department was in full swing, with four 50-ton and six 30-ton furnaces, and was producing 32 by 42 inch ingots, weighing 17 tons, which were treated in the slabbing-mill near by, in which the horizontal rolls were driven by a double-reversing engine 46 by 60 inch, and the vertical rolls by a 26 by 30 inch engine of the same type. In this mill the ingot can be reduced to any convenient section, from the common 4 by 4 inch billet to a square of 24 inches, or to a slab 36 inches in width, without changing rolls. It was at work on slabs at the time of the visit. Its annual capacity is 240,000 tons of slabs, blooms, and billets. The plate-mill next claimed attention. Here were two mills, one 90 inch, the other 132 inch, each driven by a single 54 by 66 inch Porter-Allen engine. The larger one was in use, and the slabs were very expeditiously reduced to plates; in fact this mill turns out 120,000 tons of finished plate a year, the widest being 126 inches and the longest 62 feet. The heating-furnaces are served by two travelling electric-charging machines, which take the slabs from the narrow-gauge cars and place them in the furnace, and also remove and place them on the live-roller tables when they have attained the proper temperature. These and other appliances were in excellent working order. Electro-magnets were used for handling the plates in subsequent manipulations. And then the party partook of Mr. E. F. Buffington's excellent lunch, and rose in time to return to Chicago. Many other gentlemen besides those already mentioned acted as guides, including Messrs. W. A. Field, E. B. Clark, Downes Davison, L. E. Doty, &c. It is noteworthy that the rail-mill when working on rails turns out 5400 tons of finished rails

Plate VIII.



Mines and Metallurgy Building, St. Louis Exposition

in twenty-four hours, and that the total production for 1903 amounted to 717,000 tons, equal to 5000 miles of track of 80 lbs. to the yard. The slag from some of the furnaces is granulated and converted into cement, in a plant of a capacity of 1800 barrels a day, on the spot; whilst another plant, with a capacity of 4000 barrels, is in course of construction.

RETURN TO NEW YORK.

Ultimately the party broke up in New York, the distance travelled by the main party having amounted to 1322 miles, and that travelled by the St. Louis party to 1797 miles. The whole distance was traversed without a single mishap, and without the loss of a single one of the 417 pieces of baggage belonging to the members.

The majority of the members returned to England by the steamer *Oceanic*, which left New York on November 16. Before the party left, the President entertained Sir James Kitson and others at a private dinner at his house. The following poem was written by Dr. Rossiter W. Raymond for the occasion:—

AU REVOIR.

Do you recall how yesterday,
  In your impatience to be gone,
You mixed things up, and took away
  Our hearts, while leaving us your own?

Well—here you are once more: we knew
  You would return; and here once more
We speak the parting word to you—
  The parting word we spoke before!

Yet not the same; for if you would
  Reclaim what then you left behind,
Let it be plainly understood
  That restitution is declined!

They suit us, and we'll yield them not—
  Your hearts, that we have had so long;
If you don't like the ones you got,
  It is too late to right the wrong!

Dear friends, once new, but now old friends!
  You must have known already *then*
That friendship always gives, not lends,
  And, giving, "asketh not again!"

The American visit of 1904 will always be a memorable episode in the history of the Iron and Steel Institute, to which those who took part in it will look back with pleasurable recollections of the hospitality shown by American members of the Institute, who were the hosts on the occasion of the meeting. In particular, the constant kindness and courtesy shown by Mr. C. Kirchhoff, chairman, and by Mr. Theodore Dwight, honorary secretary of the Executive Reception Committee, will not easily be forgotten. Both these gentlemen accompanied the members throughout the trip, and by their indefatigable energy contributed so largely to the conspicuous success of the meeting. At the meeting of the Council of the Institute, held in London on December 16, the Council expressed on behalf of the members their sense of indebtedness by presenting to these gentlemen pieces of plate suitably inscribed. Pieces of plate were also presented to Mr. A. Ladd Colby, who kindly undertook the direction of the St. Louis Excursion, and to Mr. T. C. Martin, past-president of the American Institute of Electrical Engineers, in appreciation of his valuable help in organising the Institute dinner in New York.

In the preparation of this report free use has been made of the information kindly supplied by the Reception Committees, as well as of the detailed accounts published in the *Ironmonger*, vol. cix., November 26, 1904, Special Number; in the *Iron Age*, vol. lxxiv., Nos. 16, 17, 18, 19; in the *Iron Trade Review*, vol. xxxvii., Nos. 43, 44, 45; in the *Engineering and Mining Journal*, October 27, 1904; in the *Engineer*, vol. xcviii., Nos. 2549, 2550, 2551, 2552; in *Engineering*, vol. lxxviii., Nos. 2028, 2029, 2030; in the *Iron and Coal Trades Review*, vol. lxix., No. 1915; in *Stahl und Eisen*, Nos. 22 and 23, 1904; and in other technical journals.

THE AMERICAN INSTITUTE OF MINING ENGINEERS.

THE invitation to the Iron and Steel Institute to hold the autumn meeting of 1904 in America was cordially endorsed by the American Institute of Mining Engineers, the society in the United States whose aims and work most nearly resemble those of the Iron and Steel Institute. The American Institute also did much in other ways to ensure the success of the meeting. The commodious offices of that society in John Street, New York, were kindly rendered available for the use of the Reception Committee, and in the election of officers for the year, distinguished authorities on iron and steel, Mr. James Gayley (president), Mr. Julian Kennedy and Mr. G. W. Maynard (vice-presidents), and Mr. F. L. Grammer and Mr. Joseph Hartshorne, were chosen. Lastly, on the suggestion of the Secretary, Dr. Rossiter W. Raymond, Honorary Member of the Iron and Steel Institute, the Council of the American Institute of Mining Engineers authorised the reprinting in the *Journal of the Iron and Steel Institute* of the papers bearing upon iron and steel published by the American society during the year. Among these were many memoirs of far-reaching importance, their titles being as follows:—

"Specifications for Cast-Iron and Finished Castings," by Dr. Richard Moldenke, New York City.

"Chemical Specifications for Pig Iron," by Edgar S. Cook, Pottstown, Pa.

"Specifications for Testing Cast Iron," by Henry Souther, Hartford, Conn.

"Standard Specifications for Pig Iron and Iron Products," by the Sub-Committee of the American Society for Testing Materials.

"Note on the Further Discussion of the Physics of Cast Iron," by William R. Webster, Philadelphia, Pa.

"Note on the Physics of Cast Iron," by Dr. Richard Moldenke, New York City.

"Specifications for Pig Iron and Iron Castings," by Robert Job, Reading, Pa.

"Standardisation of the Specifications for Cast Iron and Steel," by William R. Webster and Edgar Marburg, Philadelphia, Pa.

"Specifications for Steel Rails," by Robert W. Hunt, Chicago, Ill.

"A Decade in American Blast-Furnace Practice," by F. L. Grammer, Baltimore, Md.

"Direct-Metal and Cupola-Metal Iron Castings," by Thomas D. West, Sharpsville, Pa.

"Stock-Distribution and its Relation to the Life of a Blast-Furnace Lining," by David Baker, Cape Breton, Canada.

"Specifications for Locomotive Cylinders," by Walter Wood, Philadelphia, Pa.

"Specifications for Cast Iron," by C. R. Baird, Philadelphia, Pa.

"Specifications for Car Wheels," by Dr. Charles B. Dudley, Altoona, Pa.

"Specifications for Malleable Cast Iron," by Stanley G. Flagg, Jr., Philadelphia, Pa.

"Specifications for Iron Pipe," by Walter Wood, Philadelphia, Pa.

"The Mobility of Molecules of Cast Iron," by Alexander E. Outerbridge, Jr., Philadelphia, Pa.

"The Use of High Percentages of Mesabi Iron Ores in Coke Blast-Furnace Practice," by W. A. Barrows, Jr., Sharpsville, Pa.

"Fuel and Mineral-Briquetting," by Robert Schorr, San Francisco.

"Method of Origin of the Magnetic Iron Ores of Iron County, Utah," by E. P. Jennings, Oak Park, Ill.

"Notes on Cast Iron," by J. E. Johnson, Jr., Longdale, Va.

"Special Forms of Blast-Furnace Charging Apparatus," by T. F. Witherbee, Durango, Mexico.

"Requisites for obtaining Better Results from a Modern Blast-Furnace," by David Baker, Philadelphia.

Unfortunately the necessity of keeping the size of this volume within reasonable limits has prevented full advantage being taken of the courtesy of the American Institute of Mining Engineers. Abstracts of these important memoirs are, however, given in Section II. of the *Journal.*

The following paper, communicated by Mr. F. Louis Grammer, of Baltimore, at the Atlantic City meeting in February 1904, giving a record of the advances in American blast-furnace practice during the past ten years, will, it is thought, prove a valuable addition to the report of the American meeting:—

A DECADE IN AMERICAN BLAST-FURNACE PRACTICE.

In looking over the development of furnace practice, four steps or incidents appear as the more important factors: (1) The use of waste gas under boilers; (2) the heating of the blast; (3) the use of coke as a fuel; and (4) the use of Lake ores. Each of these steps has resulted in a doubling and trebling of the output which was possible before their introduction.

Of course improved refractory materials and better engines were essential, as was also a knowledge of chemistry, but these influences should be regarded as secondary and logical sequences to the others

The better application of the knowledge classified under these four heads represents the development in America.

The earlier volumes of the *Transactions of the American Institute of Mining Engineers* are replete with papers concerning the analysis and fusibility of slags, scaffolds, frozen furnaces, titaniferous ores, dirty walls, sulphur in metal, and a host of troubles resulting from a scattered and imperfect knowledge and an uncontrolled condition. As the facts became clearly known, men avoided trouble on the principle that "prevention is better than cure."

A decade ago lines of furnaces and cooling devices occupied the thoughts of the furnace world. Since then the advances made may be classified as follows:—

(1) Conveyors and other mechanical improvements.

(2) Metallurgical by-products.

(3) Miscellaneous.

Exigency of space precludes all but a simple mention of many of the steps, as a division of duties has been attended by a flood of ideas developed along the avenues where the intrusive finger of modern accounting has shown that leaks existed and improvements could be made.

Mechanical Conveyors.—The use of Lake ores increased tonnage so rapidly that the simple handling of ore, coke, and stone became a serious problem, and, as the properties became more and more under one control, the unnecessary moves of ore into boats to be unloaded on to docks, and to be again reloaded, were reduced. Steam-shovels, like the Marion, Bucyrus, and the Thew, were used to dig the ore out of the mines and to transfer it from the stock pile into the car. Messrs. Hughlett, McMyler, Hoover & Mason, and the Brown Conveying Company, devised means of economically unloading the ore from vessels of many hatches. By means of these devices, and large piers at the shipping points, the hours when the boats were idle were minimised.

The rolling-mill principle of keeping the passes of the rolls full of metal, and the transportation-virtue of keeping as many trains to the mile as is compatible with safety, was applied to the movement of the raw materials from the mines to the furnace. The steel cars reduce the cost of unloading by their steep bottoms, and these, with the bin-system, as at Duquesne, and car over-turners and bridges, as at Youngstown, represent the chief changes in the matter of handling raw material.

Mr. Axel Sahlin, in the *Transactions of the American Institute of Mining Engineers*, has comprehensively sketched the general points of mechanical transportation in detail, and it is therefore not necessary to enlarge upon them in this paper.

In moderate climates, where labour is expensive or troublesome, the devices have frequently paid well, and are sometimes necessary where the season for bringing the ore from mine to furnace is limited. Personally, I think that the skip-hoist, the last labour-saving step before the raw material enters the furnace, has not infrequently been introduced where the double-ring bell would have been better; this restriction, however, is not applicable to the general run of Lake ores.

Messrs. Walter Kennedy, M. A. Neeland, and E. G. Rust designed skip-hoists which may be regarded as representing the three types. Mr. Walter Kennedy's descending bucket passes at the side of the ascending bucket, and acts to some extent as a counter balance; in the hoist of Mr. Neeland, one bucket only is used, and in that designed by Mr. Rust, the ascending and descending buckets pass over and under each other.

Use of Wash Ores.—Mr. Firmstone showed me some charts of silicon and sulphur in basic metal made from wash ores varying from 10 to 12 per cent. silica, which in their regularity and percentage of off-cast compared very favourably with the best practice in Pittsburg; the furnace using these ores was equipped with a double-ring bell. I believe that such regularity with material of this character will astonish most of the Pittsburg iron-makers.

Valves.—In the question of valves, some attempt has been made to improve on the Mushroom and Berg valve-seat, the Spearman and Kennedy burner, and the cold-blast valve; save that they are made somewhat thicker and larger, they are substantially as they were a decade ago. The cutting action of Mesabi ore has suggested the multiplication of false seats and flanges on the stoves.

Tap-Hole Gun.—The Vaughn gun makes the work of stopping the hole easier on the men and is especially satisfactory if operated by compressed air.

Direct Process.—The extensive adoption of that very important link in the iron-plant—the direct process and the mixer—has suggested the undesirability of carrying a gang of specialised workmen all the week simply to carry out and break the iron on Sunday, when the converter is idle. This condition of practice has resulted in the invention of casting machines.

Casting Machines.—Mr. James Scott and Mr. Uehling have cojointly perfected the Uehling casting machine, which is a monument to their perseverance in overcoming many obstacles. The Heyl and Paterson conveyor uses lamp-black in place of lime, and pressed-steel pans in place of cast iron ones. I have always found the electric breaker at Duquesne, if used in connection with the iron chills, less expensive and more satisfactory, though the iron cast in it is not so easily handled nor so attractive in appearance. Pig-iron casting machines require more attention and are more easily thrown out of order than the electric breaker. Besides the above mentioned there are the Davies & Aiken pig-iron casting machines, whose merits commend them to some. The iron chills were necessary because of the rapid growth of the basic process, in which sand and silica are most objectionable materials. In addition, the use of iron chills saves the labour of moulding the pig-bed in sand, and from them the idea was extended of making the runners and the skimmer of iron; the latter to a great extent doing away with boils.

Slag Car.—The Weimer slag cars, lined with iron thimbles, have been introduced practically to the exclusion of all others.

Slag Disposal.—In a few plants the slag is run into pits and granulated, and then lifted on to cars by means of cranes and orange-peel buckets. This method is very economical and is especially applicable when it is necessary to dump the cinder at a great distance from the plant, more especially if it can be utilised for manufacture into cement. One disadvantage of granulating the slag is that it may cause annoyance by creating a cloud of steam at the time of casting the iron. In some plants the slag is run into dishes, or metal pans, working on a conveyor, and after it cools it is broken up and carried away for use as railroad ballast, a method which is advisable if the slag is non-slacking.

Recording Gauges, &c.—The introduction of more recording gauges for steam, air-blast, vacuum-pressure, and temperatures of blast and escaping furnace-gases, marks the advance of furnace practice into a state of better control.

The extensive introduction of the direct process and the pig casting machine has, in a few cases, caused the abandonment of the cast-house, except a small building which is required to cover the cinder and the iron in their passage to the ladles.

Dust-Pockets.—The use of Mesabi ores has made an increase in the number of dust-pockets on the gas-main. These pockets, as well as the dust-catcher, are now suspended above a track, so that when the pockets are dumped the dust will fall into the cars which have been run underneath them.

Ladle Drying.—The iron-ladles, in the absence of natural gas, are frequently dried out by burning the blast-furnace gas brought to them in a small flue.

Gas-Flues.—In a few American plants the gas-flues are not lined with brick, but the great majority use cheap fire-brick and do not copy foreigners in this practice.

At some places, as at Braddock, a satisfactory water-seal valve is used to isolate a furnace from others on a common system of gas-flues, for which purpose the Rothoff valve is extensively used.

Gas-Mains.—Almost all gas-mains are now overhead, and underground mains are avoided. Not only is the steam system universal in the modern plant, but the tendency is to make the gas-flues universal. If one of the furnaces is cold and its gas, therefore, not suited for stoves, the gas from the three other furnaces in the system will help to maintain the stove heat on the one that needs it; in a similar manner the gases from the many furnaces tend to keep the steam-pressure regular.

Boilers.—The introduction of water-tube boilers marks the further attempt to obtain the full power-possibility of the escaping gas; the Babcock & Wilcox, the Sterling, the Cahall being those the most generally adopted. The numerous water-softeners, generally based on the principle of having the carbonates precipitated by lime and the sulphates decomposed by soda, have enabled water-tube boilers to be more extensively introduced. The old idea that because there is an excess of gas and on account of the ease with which scale can be removed, cylindrical boilers should be used, has passed away.

Use of Compressed Air.—Compressed air in place of steam is being quite extensively used for such purposes as the operation of the furnace-bell and the mud-gun. It does away with the danger of burning the men and of having the water condensed around the tapping-hole and freezing around the furnace-top.

Steam Pressure.—The economies in the use of blast-furnace gas have become so extended that we now economise also on the steam obtained from the gas. In place of the 80-lb. pressure of twelve years ago, and the 60-lb. pressure of a decade earlier, we now use from 120 to 150 lb. steam pressure in connection with compound engines, condensers, and feed-water heaters. The engines are of heavy frame and the air-valves are positive acting, which gives a higher efficiency of delivery.

Without the modern engine-equipment it is probable that the present phenomenal outputs could not have been attained. Despite the fact that a finely-divided ore is reduced more rapidly than a lumpy coarse ore, its use requires a greater blast-pressure, and a larger volume of blast, else its fineness will not be taken advantage of; therefore, if the increased pressure and volume could not be supplied, the output would be smaller than when using lump ores.

I remember visiting a plant where this fact was not appreciated by the owner. It had too many engines and too many boilers, but the furnace could not get a sufficient quantity of blast to satisfy its hearth area. The steam pressure was only 60 lb. per square inch and the blast pressure only 12.

The Southwark Foundry & Machine Company, the E. P. Allis Company, the shops of the Tod Engine Company, and, latterly, several others have met the new conditions. Not, however, without some tribulation, for a 100-foot furnace requires more work to be done than a 90-foot one. This latter dimension is, in my opinion, metallurgically more desirable.

The hoist-engines in the majority of cases remain extravagant users of steam. Several plants have introduced electricity to operate the hoist.

In a few plants happily designed, where the height of the furnace is not over 90 feet, there is a surplus of steam obtainable from the furnace-gas after supplying the power demands and the stove demands. These plants sell the surplus steam to the adjacent mill. In many other plants the increased blast pressure resulting from the excessive height of the furnaces or other conditions have nullified the steam economies resulting from the improved machinery.

In some instances it has been deemed advisable to use the surplus gas to attain a higher temperature of blast (with the view of having a lower fuel consumption), rather than to sell it to the mill.

Hot-Blast Stoves.—In hot-blast stoves the bottom rings are now made of such a height that the riveting on of the door-frames, ports, and branches is done without crossing a seam. These plates are also made very much heavier than formerly because of the higher blast pressure now used. Stoves of the central combustion-chamber type seem to be gaining in popularity, and brick specially shaped for the checker-work continues to be extensively used.

Refractory Brick.—The brick manufacturer has been fully abreast with the requirements, and supplies a cheap brick for the ladle-lining, and a brick free from iron suitable to withstand abrasion for the furnace-top, and one free from alkalies and bases for use with high heats. Prior to the year 1890 a blast-furnace campaign lasted from eighteen to thirty months, now it exceeds eight years, and several furnaces have produced more than a million tons of pig iron with one lining, which has reduced the relining charges per ton of iron produced from 50 cents to less than 15 cents.

Shields.—A number of shields and protectors have been devised to protect the lining of the upper part of the furnaces from the abrasions of the stock rolling off the bell against the top walls. Of these that I have seen the best is a suspended sheet of heavy rolled steel, which was introduced by Mr. Firmstone at one of his plants. As used by him, an annular opening extended completely around the furnace-top was obtained for a gas outlet.

Water-Cooling.—At many plants having a small supply of water, a wooden waterfall is used for the purpose of cooling the condensing water for repeated use.

By-Products.—There has been a rapid growth in the case of slag cement which is placed on the market under the name of "Puzzolini," a name derived from the natural cement rock of Italy. Slag cement is used as a substitute for Rosendale cement for purposes not requiring the highest degree of reliability. Among other places, it is manufactured extensively in Chicago, Ill., Youngstown, Ohio, and at Sparrow's Point, Md. The process of manufacturing slag cement has been frequently described, and is being so improved that its consumption will probably increase.

In charcoal manufacture ammonium acetate and wood alcohol are obtained as valuable by-products, and the by-product coke-ovens yield ammonia, tar, and gas. Each of these subjects is worthy of an individual monograph, especially the by-product coke-oven, with its promised economies, both in fixed carbon, yield, and labour.

Flue Dirt.—The loss of flue dirt, in the treatment of mixtures containing a high percentage of Mesabi ore, has suggested the use of gas-washers and briquetting machines. The Steece and the Roberts washers are those in most general use. The Henry S. Mould briquetting machine has been introduced at several plants to recover the ore that has been blown over from the furnace. The loss through flue dirt can unquestionably be lessened by the study of the conditions outlined in my recent paper on "Flue Dirt and Top Pressure in Iron Blast-Furnaces."

Saving of Gas.—The introduction of a double bell, preventing the issuing of gas during the lowering of the charge, has resulted in a saving of from 10 to 15 per cent. of the gas. At several plants using a single bell the average time during which the bell was open exceeded 2 hours and 40 minutes.

Blast-Furnace Working.—Impressive as is the metallurgical practice in America, it exhibits inventive ability less than natural resource. We owe more to the regions named after that emissary of peace, Pere Marquette, and the tribes he went out to civilise and Christianise (Menominee and Gogebic), than we do to original research. It is true we have the Uehling pyrometer of American origin, which is an instrument of great precision and of great value to the furnaceman. Our records, however, are characterised by bold application rather than new ideas.

Our high furnaces do not reflect great credit on their designers, though in justice it should be said that most furnacemen were not in favour of 100-foot heights.

I have personally inspected more than sixty furnaces, and I find that the fuel consumption, other conditions being equal, is lower on furnaces of from 70 to 80 feet in height than on furnaces exceeding 90 feet. While Dr. Egleston's records do not include any very high or very large furnaces, the best fuel consumptions he quotes are in furnaces in the neighbourhood of 75 feet in height.

With very irregular ore or fuel and very expensive coke, it is a question whether a very large output per furnace is desirable. A bad cast if small is more easily taken care of by the mixer than a very large cast. The principal reasons, however, why our fuel economy has not improved (in fact it has gone backward) are as follows: The coke-ovens have been insufficient to meet the increased demand, and in order to increase production, the time of coking was shortened, which has resulted in a poorer quality of fuel. Then again the shortage of cars has caused many furnaces to be repeatedly banked, which has consequently increased the coke consumption. Many cokes formerly considered too high in ash, and therefore low in carbon, have been put on the market. Finally, the furnace mixtures used have been leaner.

The stove heating capacity has not kept pace with the blowing power, consequently lower temperatures of blast were used, resulting in a higher fuel consumption. In several instances it was considered desirable, in view of a brisk market and large profits, to use the furnace-gas for making more blast, rather than to save the coke, by using a high temperature of blast.

Generally speaking, the silicon requirements for Bessemer iron have been lower, depending upon the location of the plant and other conditions. The average percentage of silicon may be taken at 1·1 per cent. in summer, and 0·9 per cent. in winter. The lowering of silicon demands has been in the furnaceman's favour. A brisk market also has lessened the severity of the demands of the mill in sulphur. I think in some quarters there is a greater tolerance of sulphur than existed ten years ago. In other quarters the metal must be remelted if it exceeds 0·05 per cent. sulphur.

Owing to the improved preparation of raw material, the furnaceman is supposed to be able to keep the sulphur down without the use of manganese, and as high manganese percentages, through the great spluttering they occasion, preventing the forcing of the work in the converter, this element is a greater detriment in iron ores than it was in the beginning of the past decade.

The increased purchase of ore containing a higher phosphorus content has accompanied the rapid extension of the basic open-hearth steel process. It is not unusual upon the shutting down of the converter on Saturday afternoon, while the metal is being run into the chills or through the pig casting machine, to put a basic mixture in the furnace, a procedure which is especially desirable if the furnace capacity of direct-process metal is sufficient for the converter capacity and need not be supplemented by remelting the Sunday's product in a cupola-furnace. The direct process, with the great advantages afforded by the closing down of the cupolas, has been greatly extended, and molten metal in Pittsburg and Cleveland is carried in 20-ton cars for a distance of more than 5 miles.

The use of multiple tuyeres has not always been attended with satisfaction, and a more conservative estimate of their benefits now prevails.

The drying of furnaces preparatory to "blowing-in" is now much shorter in time than was the practice a decade ago, many thinking a week quite sufficient. During the blowing-in period the burden is now increased more rapidly, and the quantity of wood used is very much less than formerly. I know a very successful operator who uses no more than a cartload of wood for blowing-in a large furnace, and a few who light the furnaces in starting by means of red-hot iron bars introduced through the tuyeres, while the blast is on. Red-hot charcoal also is satisfactorily used by some who blow it through the tuyeres during the starting of the blowing-in. The hot-blast stoves can now be heated higher previous to starting than was formerly practicable, owing to the use of natural gas or the universal gas-main.

A saner treatment of the tap-hole now prevails, due to the recognition that an exceptionally large product for a single day means little, and as a consequence the last portion of iron in the crucible is not drawn out by long prolonged blowing at the tap-hole. The blowing at the tap-hole leads to breakouts, on account of the heating up of the furnace front.

The blowing away of furnace bell-and-hopper by slips, which frequently occurred after the introduction of Mesabi ore, is now unusual. This usually disastrous irregularity was then attributed to a so-called dust-explosion, but I think this assumption is wrong, and the irregular working, even with high percentages of Mesabi ore in the charge, can be obviated.

The proportion of Mesabi ore used in the ore-mixture has, in exactly a decade, increased from 25 to 100 per cent., a furnace in Pittsburg having been blown-in recently with the ore-mixture composed entirely of Mesabi ore.

The introduction of gas-engines at the Buffalo plant of the Lackawanna Steel Company has marked an important epoch in blast-furnace practice. By eliminating boilers, and thus combining the duties of boiler and blowing-engine, economies are promised amounting to 20 per cent.

Through the courtesy of Mr. Wehrum, formerly the general manager of the Lackawanna Steel Company, the following data on the company's gas-engines have been contributed:—

"The distribution of the units of horse-power of blast-furnace gas-engines installed in Europe prior to February 1902 was: England, 600; Italy, 1800; Russia, 2230; Austria, 2840; France, 7400; Belgium, 7600; Luxemburg, 15,400; and Germany, 44,665—making a total of 82,535 horse-power.

"Blast-furnace gas in gas-motors is 37 per cent. higher in efficiency than that used to produce steam, and I estimate that the engines introduced at the plant of the Lackawanna Steel Company under my administration show an economy of fully 300 per cent. more than that of the single-condensing steam blowing-engines, which is equivalent to a saving of 12·50 dollars per horse-power per year, by the introduction of blast-furnace gas-motors. Gas-engines are now installed and in operation at the Buffalo plant of the company to the extent of some 5100 horse-power."

The above-mentioned quantity of horse-power (82,535) has since been increased to 297,050, which is distributed among the various gas-engine makers as shown in Table I.

Table I.—*Blast-Furnace Gas-Engines* (*exceeding* 200 *Horse-Power*) *Completed or in Course of Construction, October* 31, 1903.

	Deutz.	Koerting.	Nuernberg.	Oechelheuser.	Cockerill.	Total.
Number of engines . .	123	70	57	41	116	407
Total horse-power . .	49,225	83,475	61,350	27,400	75,600	297,050
Average horse-power .	400	1,192	1,075	667	652	730

Considering the fact that about two-thirds of the gases are now used for the production of power and one-third for heating the stoves, the subject is well worthy of study.

Mr. Uehling makes a statement, that for each ton of pig iron produced per hour there will be available 800 horse-power for sale or for use in connection with the rolling-mills connected with the blast-furnace plant, and Mr. F. du P. Thompson, who assisted Mr. Wehrum at the Lackawanna Steel Company's plant, is of the opinion that 500 horse-power per ton of pig iron produced per hour would more nearly approach practical working.

The blast-furnace has always been regarded as representing a high degree of efficiency. In the direct process the heat contained in the molten iron has been saved, and doubtless ere long the heat of the molten slag also will be utilised. But it is in the line of using waste gases that our signal economies have been scored. First, in using it under the boilers, then in using it under the stoves, then in sealing the top of the blast-furnace with a double bell, then in selling the excess waste gas to the mill in the form of steam, and now, after continuously demanding more from it, we hope to receive more by the introduction of gas-engines.

In the Metallurgical Congress, which I suppose will form a part of the Louisiana Purchase Centenary, it will be appropriate to record the progress of that plant of unrivalled natural resources, viz., the Colorado Fuel and Iron Company, situated in what was then the great American desert, and what is now one of the greatest coalfields and ore deposits of the world.

Although our coke consumption remains between 1750 and 2100 pounds per ton of metal produced, our daily output per furnace has jumped from 350 to 500 tons and more in a decade, and the total yearly output of pig iron, according to Mr. Swank, has grown from about 8,000,000 tons to 18,009,252 tons in 1903. This rapid increase in the production can be understood when it is known that one 500-ton furnace has been erected, and produced iron within one year and one day after the pick was first driven into the ground.

In the iron world it has been proven that high wages need not mean increased cost of production. The region between the Great Lakes and the Connellsville coalfield is still regarded as being a section where the most advantages are found, possessing easy access to high-grade cokes, the best ores, the most skilled and ambitious labour, the greatest mechanical ingenuity, and the best markets. Colorado and Alabama also hold strong positions.

While the decade has recorded the abandonment of many plants economically unfit, it has been a period of great activity in building new plants in the localities above mentioned, as well as in Canada and Mexico. The tendency has been towards fewer units and larger units, towards a keener appreciation of the reduction in cost resulting from using a large output as a divisor, particularly with reference to the reduction of the cost of management and fixed charges.

A series of observations by barometer and hygrometer emphasise the disadvantages of high humidity, and have led in a few instances, where there were hot, moist engine-rooms, to the supply of air from outside the building by means of especially constructed pipes. This also is a line of investigation receiving the attention of some of our foremost furnace managers.

I cannot close this brief record without the mention of the one whom I think has most clearly discerned the trend of events. Mr. James Gayley early saw the possibilities of Mesabi ores and the methods of handling them, as he also saw the advantages of a low bosh and a large hearth. Both in justice and with a sense of personal loyalty, I feel that the name of Mr. James Gayley should be placed permanently among those who have contributed so much to the splendid development of the blast-furnace practice during recent years.

CHANGES IN THE AMERICAN IRON INDUSTRY SINCE THE IRON AND STEEL INSTITUTE MEETING OF 1890.*

BY B. E. V. LUTY.

WHEN the members of the Iron and Steel Institute visited the United States fourteen years ago they found a state of development in the American iron and steel industry which they had not anticipated. They were treated to a genuine surprise. Not because there have not been startling changes in the industry since then, but rather because these changes have been so well advertised, the visiting members of the Institute this year will find comparatively little cause for wonder. In the exploitation of new sources of raw materials, in tonnage and equipment of plants, and in the employment of steel in new ways the American iron and steel trade has made remarkable progress. It is proposed here to recount briefly the more important changes that have occurred since the last visit of the Institute.

TONNAGE OUTPUT.

For four years the production of 9,202,703 gross tons in pig iron in 1880 remained a record, but the following decade saw this substantially doubled by the production of 18,009,252 gross tons in 1903. Steel has shown a much greater increase, the total tonnage of Bessemer and open-hearth ingots in 1890 constituting 46 per cent. of the pig-iron production, while in 1903 the proportion had risen to 80 per cent. Obviously the greater part of the proportionate increase has been due to the decadence in the manufacture of wrought iron, but not all of it. There has been an appreciable displacement of iron castings by rolled forms. The production of open-hearth ingots rose from 513,232 gross tons in 1890 to 5,837,789 gross tons in 1903, while Bessemer ingots increased from 3,688,871 tons to 8,577,228 tons. Roughly speaking, the production of puddled iron has dropped from 2½ million tons, weighted in the rolled form, to less than a million tons.

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* This paper is reprinted by permission from the *Iron Trade Review*, Cleveland, Ohio, of October 27, 1904.

THE MESABI IRON ORE RANGE.

In 1890 the four older iron ranges of the Lake Superior region were well developed, even the newest, the Vermilion and Gobegic, having been substantial producers for the five preceding years, but the Mesabi was wholly unknown as a producer, and its future importance scarcely dreamt of by prospectors. In 1903 the four old ranges produced only 26·5 per cent. more than they did in 1890, while the Mesabi production last year exceeded the combined production of the other four ranges. To the beginning of 1890 the old ranges had shipped 48,293,628 tons. Two of them, the Marquette and Menominee, together shipped 2,000,000 tons a year ten years earlier. In less than ten years following the initial shipments of 4245 tons in 1892, the Mesabi range had rolled up a greater total than the older ranges had shown in several decades ending with 1889. The following table shows the shipments in gross tons:—

	1890.	1903.	Total through 1903.
Marquette	2,993,664	3,040,245	69,746.409
Menominee	2,282,237	3,741,284	45,988,855
Vermilion	880,014	1,676,699	20,738,205
Gogebic	2,847,810	2,912,912	40,731,186
Total, old range . .	9,003,725	11,371,140	177,204,655
Mesabi	...	12,892,542	66,640,349
Grand total . . .	9,003,725	24,281,595*	243,865,237†

The earlier development of the Mesabi range was of bodies lying close to the surface, whereby with a small stripping expense large quantities of ore could be gained by the steam shovel, and a remarkably low cost of mining resulted, being but a small fraction of the cost of mining even the more accessible deposits of the old range. Of late, however, the attraction of the Mesabi range has not been simply the extremely low cost of mining, as more difficult propositions have been undertaken. The relative low cost of Mesabi mining assumes an alternative in the use of Mesabi and old range ores; yet the fact that the known reserves of the Mesabi range are three or more times those of the four old ranges combined, together with the fact the old ranges are under much closer ownership by the older steel producers, leaves no alternative, and Mesabi range shipments must more and more preponderate as the years go by.

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* Including 17,913 tons miscellaneous. † Including 20,233 tons miscellaneous.

Blast-Furnace Development.

The Mesabi ores, being fine and soft, are distinct from most of those of the four old ranges, and introduce a different element in the smelting operation. In the past few years the necessity of using these ores in increasing quantities has accordingly been the dominant influence in blast-furnace development, and has led to an apparent, if not a real, retrogression in the matter of size of stack.

When the members of the Iron and Steel Institute visited the United States in 1890, the largest blast-furnaces they saw were furnaces H and I of the Edgar Thomson group of the Carnegie interests. These furnaces had just been completed during the year, and were each 90 by 22 feet. They have since been altered, and are now 91 by 22 and 90 by 20 feet respectively. In 1896-97 a distinctly new era in blast-furnace construction was marked by the completion of the four Duquesne furnaces, originally designed to be 100 by 22 feet, with a capacity of 25,000 cubic feet. The bosh of No. 4 as actually built, however, was one foot smaller, while the bosh of Nos. 2 and 4 has since been enlarged to 23 feet. These furnaces were built with two distinct ends in view: (1) the employment of large percentages of Mesabi ore; (2) a greatly increased output, partly through the increased size of the stock, but also through increased pressure and volume of air. Two were equipped with ten 7-inch tuyeres, and two with twenty 5-inch tuyeres.

This new type of furnace was followed by many, but not all steel works. The Sharon Steel Company intended building two furnaces 100 by 22 feet, but after blowing in the first, in September 1901, concluded to follow it with two smaller stacks instead of one large one, and as a result furnaces 2 and 3 at this plant are now 85 by 19 feet.

While the value of the 600-ton furnace has been open to comparatively slight question, it seems to be well settled that for the production of foundry iron, or perhaps a better expression may be, to meet the requirements of a merchant furnace desiring to produce foundry, Bessemer, or basic iron at will, a somewhat smaller stack is preferable. Of this type the following are instances: Toledo, Ou furnace, 80 by 20, blown in May 31, 1903; Adrian furnace, D. Bois, Pa., 80 by 19, blown in August 10, 1903; Cleveland furnace, 80 by 20, blown in August 21, 1903, and the two Buffalo and Susquehanna furnaces at Buffalo, N.Y., 80 by 20, completed this year. These are all merchant furnaces, and their smaller size is due to no question of economy with the owners; they are thoroughly modern in equipment, with ample blowing power and excellent facilities for handling the raw materials.

The new furnaces at Buffalo, N.Y., not yet all completed, of the Lackawanna Steel Company (which, by the way, is now rounding out the largest single iron and steel plant in the world), well illustrate the strong influence of the Mesabi ores. These furnaces are 6 feet shorter, yet 2 feet larger bosh diameter, than the original Duquesne furnaces, the departure being chiefly to secure an increased outward slope of the walls from the top to the bosh, this "batter" being 0·82 inch to the foot with the Lackawanna furnaces. The Clairton furnaces, completed last year, have a "batter" of 0·7 inch, and even this exceeds that of earlier large furnaces. The tendency is clearly back to the slopes prevailing with the old hand-filled furnaces, still in operation.

There is still disagreement among the doctors, however, as to the most desirable remedy for the explosions and other difficulties attending the use of very high percentages of Mesabi ores. Until within the past two or three years dependence was placed largely upon explosion doors, but lately a number of furnaces have been built with an absolutely closed top, designed to stand a pressure of 35 pounds per square inch, and the position has been quite ably defended that the explosion doors greatly accentuate the frequency and force of the explosions they were adopted to relieve. Heterogeneous and stratified filling have also been urged, and the former has been shown very successful with hand-filled furnaces. Neither is at present possible with automatic filling. The Lackawanna furnaces have a movable oval deflector, from which results are expected.

THE DECADENCE OF THE PUDDLING FURNACE.

The supplanting of wrought iron by mild steel in the United States seems to have lagged behind the similar movement in England. In the absence of accurate statistics, it is fairly certain that the maximum production of puddled iron in the United States occurred in 1890. The relative percentage had of course been decreasing since the first advent of soft steel. The decline of puddling seems to have proceeded most rapidly in 1892, as a summary of puddling furnaces in the Pittsburg district showed a decline from 1·103 to 828, or 25 per cent. during the year. The leading steel-makers, like

Carnegie, Jones & Laughlins, and others, had retained the puddling furnace only under sufferance while they prosecuted a campaign of education, and about this time Jones & Laughlins finally abandoned it.

Within the past few years some important consumers have declared unequivocally for wrought iron for certain purposes, and the distinctively iron industry will live, even without such favour, since it furnishes a means of utilising certain grades of scrap which are otherwise of little use.

THE GEOGRAPHICAL MOVEMENT.

The greatly increased importance of the Lake Superior region as a source of iron ore, and the decline of wrought iron to make way for steel have led to interesting geographical movements since 1890. In that year the eastern half of the State of Pennsylvania made substantially as much pig iron as the western half, while there were six blast-furnaces on the shore of Lake Erie, five at Cleveland, and one at Tonawanda, N.Y. (which may be treated as a lake port). In 1890 the western half of Pennsylvania made one-fourth of the country's total production of 9,000,000 tons; now it is making more than one-third of a total which has doubled. The eastern half of the State has slightly declined in actual tonnage, and now makes only 10 per cent. of the country's total pig iron production, and less than one-third as much as the western half of the State. The shore of Lake Erie to-day is dotted at intervals with blast-furnaces, and there are now twenty-five furnaces built or being built, of which thirteen are in Buffalo, N.Y., district, at the extreme eastern end of the lake, and the balance in the State of Ohio.

Alabama, of which such great hopes were entertained in 1890, has largely increased its production, but has barely contributed the same quota to the country's total pig-iron production. The state has become a steel-maker, and enjoys the distinction both of being the first to make open-hearth steel rails in commercially important proportions, and of using, at least in an experimental way, the pneumatic process as a prelude to the regular basic open-hearth process, to reduce silicon and carbon.

THE TIN-PLATE INDUSTRY.

A subject which came in for no little discussion and good-natured banter on the Institute's last visit to America was the possibility of a tin-plate industry being established here. As a result of long and arduous work on the part of the friends of tin-plate, a tariff duty of 2.2 cents per pound had been incorporated in the McKinley law, just passed and put into effect July 1, 1890. The tin-plate duty, however, was not to go into effect until July 1 of the following year. There was disposition on the part of friends of the Welsh tin-plate industry to doubt whether the United States could establish a tin-plate industry of its own of commercial proportions. This doubt was certainly shared by Congress, as shown by a peculiar provision inserted in the McKinley law, which is not without interest now that the outcome is so well known. This provision was that at the end of six years of the 2.2 cent duty, or on July 1, 1897, tin-plate should be wholly free of duty (the previous duty had been 1 cent per pound) unless in any of the six fiscal years the domestic production should have equalled one-third of the imports in any one of these years. In other words, the year of greatest domestic production was pitted against the year of least imports, and was to equal only one-third such minimum. The provision was made further favourable by excluding from the reckoning of imports such tin-plates as should be imported for rebate or re-export purposes, and including in the reckoning of domestic production such fine sheets or black plates as should be stamped and thereafter tinned or terne plated. Apparently such provision was useless, yet it actually gave some concern at the outset. In the third year, however, the provision was more than met. In 1894 the Democratic party having come into power, the duty was reduced to 1.2 cents per pound, but this did not stop the growth of the industry; if anything it encouraged it, since it showed the worst that could reasonably be expected from the enemies of the tariff. In 1897 the duty was increased to 1.5 cents, the Republican party having regained power.

The production of tin-plate and terne-plate in the United States has been as follows, in gross tons, the production made from imported black plate being included, but since 1894 such production has been entirely negligible :—

1891	999	1898	326,915
1892	18,803	1899	360,875
1893	55,182	1900	302,665
1894	74,260	1901	390,291
1895	113,666	1902	366,000*
1896	160,362	1903	400,000†
1897	256,598		

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* Close estimate. † Rough estimate.

The production of the current year, 1904, will likely surpass all previous records.

The increase in production up to and including the year 1897 represents substantially the inroads made upon the import trade. There was no great increase in domestic consumption, since in 1890 and for some years previous our imports had averaged from 300,000 to 325,000 tons, of which from 50,000 to 75,000 tons were required for the "drawback trade," being re-exported as containers, with the duty refunded, representing therefore a domestic consumption of, say, 250,000 tons annually. It was this trade alone which the domestic industry could hope to capture. Since about January 1, 1898, imports of tin-plate for domestic consumption have been negligible, and the increase in domestic production of between 100,000 and 150,000 tons represents an increased consumptive demand, due to the increase in population and an increasing per capita consumption.

Something has been done by the leading American tin-plate interest towards capturing from the Welsh makers the "rebate trade" as well. This movement has only been important, and even then not very important, during the past two years. In October 1902 an arrangement was made with the tonnage men in those of the tin-plate mills which are union, whereby they would work at a concession of 25 per cent. in wages on tin-plate intended for the rebate trade. This concession has since been reduced to 12½ per cent., and is therefore almost negligible, particularly since the tonnage labour does not, as in Wales, represent the great bulk of the labour cost of a box of tin-plate. The men covered by the agreement are only the roller, heater, double, catcher, screwboy, and shearman. Their wages are paid per ton, but the following table reduces them to the box, with the rebate at 12½ per cent.:—

	Total.	Rebate.
100-lb. plates	45·76 c.	5·72 c.
95-lb. plates	45·16 c.	5·65 c.
90-lb. plates	42·79 c.	5·35 c.

In the six fiscal years ended with June 30, 1907, the quantity of imported tin-plate on which drawback was paid by the government has been 761,764,074 pounds, an average of 126,960,676 pounds per year. The imports in the same period have exceeded this by 93,383,435 pounds, an average of 15,563,906 pounds per year, equal to 6948 gross tons.

Fourteen years ago the Iron and Steel Institute found no American tin-plate industry; this month they find one which for seven years has fully supplied a domestic demand which has increased by one-half.

Few parallels can be found to the improvement in equipment and processes which has marked these comparatively few years in the American tin-plate industry. Nor was this unnatural, considering the conditions. A very large profit was vouchsafed to the pioneers, if they could actually succeed in making tin-plate at all. Many men who had worked for the imposition of the McKinley tin-plate duty shrank from investing their money afterwards, because there was a remarkable change in the political aspect, and their places were taken quite freely by men who had no previous experience in any branch of iron and steel manufacture. Naturally they made innovations. At this late date the feelings of no one will be hurt by the bald statement, that many of the innovations were made purely through ignorance of the "right" or old way. Nor was it unnatural that in building wholly new departures should be made. In Wales new tin mills were not being built.

In the hot mill, the Welsh practice of two stands of rolls, one roughing and one finishing, was abandoned, and a single stand used for the whole work. Instead of rolls 16 to 18 inches in diameter, as in Wales, rolls 20 to 22 inches in diameter were employed at first, and the size was shortly increased to 24 inches, while 26 inches is now the standard. Instead of rolling a "cut and a half," or a 20 by 42 sheet, making one 20 by 28 and one 14 by 20, packs were rolled 20 by 56, each sheet making two sheets 20 by 28, and even packs 28 by 60 making three of 20 by 28 have been successfully rolled. Not all of the increased output was due either to skill or equipment; the workmen's organisation was more liberal in fixing the tonnage allowance. This is shown by the fact that without changes in equipment or increased skill, the Welsh output has in the past few years been very materially increased.

An early innovation was the general adoption of the squaring shear for squaring and shearing the pack, against the Welsh practice of marking out the pack and using the doubling shear. The roll lathe has been generally employed for turning the rolls, in place of turning them in the housings by a slow motion.

More important innovations were the introduction of large boxes for annealing, with mechanical means for charging them into the furnace and withdrawing them, and the arrangement of cold mills tandem, with conveyers and means for throwing out defective sheets after the second pass.

Of general improvements the most important has certainly been the electric three-motor travelling crane, which performs a variety of very useful functions, and has wholly supplanted the jib cranes and their occasional successors, the pneumatic cranes.

In all this there has been no important departure from former principles, nor was there in the general adoption of branning and dusting machines in the tinhouse—simply the natural use of machinery in a country where labour is dear. In fundamental processes some changes have, however, been made. The first important one of these is the "Monessen system," employed at the Monessen, Pa., works of the American Tin-plate Company, the invention and patent of W. H. Donner. It is rather a principle than a system, being capable of being worked in a variety of ways. It consists essentially in confining each of the successive operations of roughing, rolling the pairs, rolling the fours, and finishing the eights, to a separate stand of rolls, or grouping these operations, as the roughing on one stand, the pairs on another, and the fours and eights on another, or rather half the product of the first two stands on each of the two succeeding stands. Its success, where success was doubtful in the minds of those who adhered to old principles, is due to the fact that the continual changes in the contour of the rolls, working the old style, is due in large part to the fact that they are called upon to do such a variety of work, from roughing short hot bars to finishing long packs of eights at a lower temperature. The rolls are turned right and kept right, rather than being controlled by the skill of the men.

A more radical innovation is the Bray semi-continuous mill, the invention and design of C. W. Bray, chief mechanical engineer of the American Sheet and Tin-plate Company, and installed at the Monongahela works, within the city limits of Pittsburg. Briefly, its operation consists in heating the bars in a continuous heating furnace, roughing them rapidly in a continuous mill of five stands, with tables, automatically matching the bars, rolling them in a continuous mill of two stands, and then automatically doubling them into fours. From this point the old style is followed, with two heatings, two rollings, and a doubling, all by hand. This mill has been found better adapted to the heavier than the lighter gauges, and accordingly the company is now installing a mill on this principle at Sharon for the manufacture of sheets. It will have one more stand in the continuous mill, and is intended to carry the product far enough that it may be finished by hand with but one additional heating.

The Bennett catching device has been in successful use in a number of tinhouses, and performs the function of the "iron man" in Wales, being naturally more in favour on account of the greater saving in labour in the United States. The brush system, first used at Martins Ferry, Ohio, has gained favour as reducing and making more uniform the tin coating. It consists of a fine wire brush pressing on the under side of each of the finishing rolls in the oil, whereby the tin adhering to the finishing rolls is largely removed. By this means the coating has been got down to 1·8 pounds per box of 112 sheets, 14 by 20.

OBITUARY.

Sir Lowthian Bell, Bart., Past-President, died on December 21, 1904, at his residence, Rounton Grange, Northallerton, in his eighty-ninth year. In his person the Iron and Steel Institute has to deplore the loss of its most distinguished and most valuable member. From the time when the Institute was founded as the outcome of an informal meeting at his house, until his death, he was a most active member, and regularly attended the general meetings, the meetings of Council, and the meetings of the various committees on which he served.

Sir Lowthian Bell was the son of Mr. Thomas Bell (of Messrs. Losh, Wilson, & Bell, iron manufacturers, Walker-on-Tyne), and of Catherine, daughter of Mr. Isaac Lowthian, of Newbiggin, near Carlisle. He was born in Newcastle on February 15, 1816, and educated, first at Bruce's Academy, in Newcastle, and afterwards in Germany, in Denmark, at Edinburgh University, and at the Sorbonne, Paris. His mother's family had been tenants of a well-known Cumberland family, the Loshes of Woodside, near Carlisle, one of whom, in association with Lord Dundonald, was one of the first persons in this country to engage in the manufacture of soda by the Leblanc process. In this business Sir Lowthian's father became a partner on Tyneside. Mr. Bell had the insight to perceive that physical science, and especially chemistry, was bound to play a great part in the future of industry, and this lesson he impressed upon his sons. The consequence was that they devoted their time largely to chemical studies.

On the completion of his studies, Lowthian Bell joined his father at the Walker Iron Works. Mr. John Vaughan, who was with the firm, left about the year 1840, and in conjunction with Mr. Bolckow began their great iron manufacturing enterprise at Middlesbrough. Mr. Bell then became manager at Walker, and blast-furnaces were erected under his direction. He became greatly interested in the ironstone district of Cleveland, and as early as 1843 made experiments with the ironstone. He met with discouragements at first, but was rewarded with success later, and to Messrs. Bell Brothers largely belongs the credit of developing the ironstone field of Cleveland. Mr. Bell's father died in 1845, and the son became managing partner. In 1852, two years after the discovery of the Cleveland ironstone, the firm acquired ironstone royalties first at Normanby and then at Skelton in Cleveland, and started the Clarence Iron Works, opposite Middlesbrough. The three blast-furnaces here erected in 1853 were at that time the largest in the kingdom, each being 47½ feet high, with a capacity of 6012 cubic feet. Later furnaces were successively increased up to a height of 80 feet in 1873, with 17 feet to 25 feet in diameter at the bosh, 8 feet at the hearth, and about 25,500 cubic feet capacity. On the discovery of a bed of rock salt at 1127 feet depth at Middlesbrough, the method of salt manufacture in vogue in Germany was introduced at the instance of Mr. Thomas Bell, and the firm of Bell Brothers had thus the distinction of being pioneers in this important industry in the district. They were also among the largest colliery proprietors in South Durham, and owned likewise extensive ironstone mines in Cleveland, and limestone quarries in Weardale. At the same time Mr. Bell was connected with the Washington Aluminium Works, the Wear blast-furnaces, and the Felling blast-furnaces.

Although Sir Lowthian Bell was an earnest municipal reformer and member of Parliament, he will best be remembered as a man of science. He was mayor of Newcastle in 1863, when the British Association visited that town, and the success of the gathering was largely due to his arrangements. As one of the vice-presidents of the chemical section, he contributed papers upon thallium and the manufacture of aluminium; and, jointly with the late Lord Armstrong, edited the souvenir volume entitled "The Industrial Resources of the Tyne, Wear, and Tees." In 1873, when the Iron and Steel Institute visited Belgium, Mr. Bell presided, and delivered in French an address on the relative industrial conditions of Great Britain and Belgium. Presiding at the Institute's meeting in Vienna in 1882, he delivered his address partly in English and partly in German, and expressed the hope that the ties between England and Austria should be drawn more closely.

On taking up his residence permanently at Rounton Grange, near Northallerton, Sir Lowthian made a present to the city council, on which he had formerly served for so many years, of Washington Hall and grounds, and the place is now used as a home for the waifs and strays of the city. It is known as Dame Margaret's Home, in memory of Lady Bell, who died in 1886. This lady, to whom he was married in 1842, was a daughter of Mr. Hugh Lee Pattinson, F.R.S., the eminent chemist and metallurgist.

Sir Lowthian earned great repute as an author. He was a prolific writer on both technical and commercial questions relating to the iron and steel industries. His first important book was published in 1872, and was entitled "Chemical Phenomena of Iron Smelting: An Experimental and Practical Examination of the Circumstances which Determine the Capacity of the Blast-Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be Operated upon." This book, which contained nearly 500 pages, with many diagrams, was the direct outcome of a controversy with the late Mr. Charles Cochrane, and gave details of nearly 900 experiments carried out over a series of years with a view to finding out the laws which regulate the process of iron smelting, and the nature of the reactions which take place among the substances dealt with in the manufacture of pig iron. The behaviour of furnaces under varying conditions was detailed. The book was a monument of patient research, which all practical men could appreciate. His other large work—covering 750 pages—was entitled "The Principles of the Manufacture of Iron and Steel." It was issued in 1884, and in it the author compared the resources existing in different localities in Europe and America as iron-making centres. His further investigations into the manufacture of pig iron were detailed, as well as those relating to the manufacture of finished iron and steel.

In 1886, at the instance of the British Iron Trade Association, of which he was then President, he prepared and published a book entitled "The Iron Trade of the United Kingdom compared with other Chief Ironmaking Nations." Besides these books and numerous papers contributed to scientific societies, Sir Lowthian wrote more than one pamphlet relating to the history and development of the industries of Cleveland.

In 1876 Sir Lowthian was appointed a Royal Commissioner to the Centennial Exhibition at Philadelphia, and wrote the official report relating to the iron and steel industries. This was issued in the form of a bulky Blue-book.

As a director of the North-Eastern Railway Company Sir Lowthian prepared an important volume of statistics for the use of his colleagues, and conducted exhaustive investigations into the life of a steel rail.

The majority of his papers were read before the Iron and Steel Institute, but of those contributed to other societies the following may be mentioned:—

Report and two papers to the second Newcastle meeting of the British Association in 1863, already mentioned. "Notes on the Manufacture of Iron in the Austrian Empire," 1865. "Present State of the Manufacture of Iron in Great Britain," 1867. "Method of Recovering Sulphur and Oxide of Manganese, as Practised at Dieuze, near Nancy," 1867. "Our Foreign Competitors in the Iron Trade," 1868; this was promptly translated into French by Mr. G. Rocour, and published in Liége. "Chemistry of the Blast-Furnace," 1869. "Preliminary Treatment of the Materials Used in the Manufacture of Pig Iron in the Cleveland District" (Institution of Mechanical Engineers, 1871). "Conditions which Favour, and those which Limit, the Economy of Fuel in the Blast-Furnace for Smelting Iron" (Institution of Civil Engineers, 1872). "Some supposed Changes Basaltic Veins have Suffered during their Passage through and Contact with Stratified Rocks, and the Manner in which these Rocks have been Affected by the Heated Basalt": a communication to the Royal Society on May 27, 1875. "Report to Government on the Iron Manufacture of the United States of America, and a Comparison of it with that of Great Britain," 1877. "British Industrial Supremacy," 1878. "Notes on the Progress of the Iron Trade of Cleveland," 1878. "Expansion of Iron," 1880. "The Tyne as connected with the History of Engineering" (Institution of Mechanical Engineers, 1881). "Occlusion of Gaseous Matter by Fused Silicates and its possible connection with Volcanic Agency:" a paper to the third York meeting of the British Association, in 1881, but printed in the *Journal of the Iron and Steel Institute*. Presidential Address on Iron (Institution of Mechanical Engineers, 1884). "Principles of the Manufacture of Iron and Steel, with Notes on the Economic Conditions of their Production," 1884. "Iron Trade of the United Kingdom," 1886. "Manufacture of Salt near Middlesbrough" (Institution of Civil Engineers, 1887). "Smelting of Iron Ores Chemically Considered," 1890. "Development of the Manufacture and Use of Rails in Great Britain" (Institution of Civil Engineers, 1900). Presidential Address to the Institution of Junior Engineers, 1900.

To him came in due course honours of all kinds. When the Bessemer Gold Medal was instituted in 1874, Sir Lowthian was the first recipient. In 1895 he received at the hands of the King, then Prince of Wales, the Albert Medal of the Society of Arts, in recognition of the services he had rendered to arts, manufactures, and commerce by his metallurgical researches. From the French government he received the cross of the Legion of Honour. From the Institution of Civil Engineers he received the George Stephenson Medal, in 1900, and, in 1891, the Howard Quinquennial Prize which is awarded periodically to the author of a treatise on Iron.

For his scientific work Sir Lowthian was honoured by many of the learned societies of Europe and America. He was elected a Fellow of the Royal Society in 1875. He was an Hon. D.C.L. of Durham University; an LL.D. of the Universities of Edinburgh and Dublin; and a D.Sc. of Leeds University. He was one of the most active promoters of the Durham College of Science by speech as well as by purse; his last contribution was made only a short time ago, and was £3000, for the purpose of building a tower. He had held the presidency of the North of England Institution of Mining and Mechanical Engineers, and was the first president of the Newcastle Chemical Society.

Sir Lowthian was a director of the North-Eastern Railway Company since 1865. For a number of years he was vice-chairman, and at the time of his death was the oldest railway director in the kingdom. In 1874 he was elected M.P. for the Borough of the Hartlepools, and continued to represent the borough till 1880. In 1885, on the advice of Mr. Gladstone, a baronetcy was conferred upon him in recognition of his great services to the State. Among other labours he served on the Royal Commission on the Depression of Trade, and formed one of the Commission which proceeded to Vienna to negotiate Free Trade in Austria-Hungary in 1866. For the County of Durham he was a Justice of the Peace and Deputy Lieutenant, and High Sheriff in 1884. He was also a Justice of the Peace for the North Riding of Yorkshire and for the city of Newcastle. He served as Royal Commissioner at the Philadelphia Exhibition in 1876, and at the Paris Exhibition of 1878. He also served as Juror at the Inventions Exhibition in London, in 1885, and at several other great British and foreign Exhibitions.

Of the Society of Arts he was a member from 1859. He joined the Institution of Civil Engineers in 1867, and the Chemical Society in 1863. He was a past-president of the Institution of Mechanical Engineers, and of the Society of Chemical Industry; and at the date of his death he was president of the Institution of Mining Engineers. He was an honorary member of the American Philosophical Institution, of the Liége Association of Engineers, and of other foreign societies. In 1882 he was made an honorary member of the Leoben School of Mines.

In the Iron and Steel Institute he took special interest. One of its original founders in 1869, he filled the office of president from 1873 to 1875, and was, as already noted, the first recipient of the gold medal instituted by Sir Henry Bessemer. He contributed the following papers to the *Journal* of the Institute in addition to Presidential Addresses in 1873 and 1874: (1) "The Development of Heat, and its Appropriation in Blast-furnaces of Different Dimensions" (1869). (2) "Chemical Phenomena of Iron Smelting: an experimental and practical examination of the circumstances which determine the capacity of the blast-furnace, the temperature of the air, and the proper conditions of the materials to be operated upon" (No. I. 1871; No. II. 1871; No. I. 1872). (3) "Ferrie's Covered Self-coking Furnace" (1871). (4) "Notes on a Visit to Coal and Iron Mines and Ironworks in the United States" (1875). (5) "Price's Patent Retort Furnace" (1875). (6) "The Sum of Heat utilised in Smelting Cleveland Ironstone" (1875). (7) "The Use of Caustic Lime in the Blast-furnace" (1875). (8) "The Separation of Carbon, Silicon, Sulphur, and Phosphorus in the Refining and Puddling Furnace, and in the Bessemer Converter" (1877). (9) "The Separation of Carbon, Silicon, Sulphur, and Phosphorus in the Refining and Puddling Furnaces, in the Bessemer Converter, with some Remarks on the Manufacture and Durability of Railway Bars" (Part II. 1877). (10) "The Separation of Phosphorus from Pig Iron" (1878). (11) "The Occlusion or Absorption of Gaseous Matter by fused Silicates at High Temperatures, and its possible Connection with Volcanic Agency" (1881). (12) "On Comparative Blast-furnace Practice" (1882). (13) "On the Value of Successive Additions to the Temperature of the Air used in Smelting Iron" (1883). (14) "On the Use of Raw Coal in the Blast-furnace" (1884). (15) "On the Blast-furnace value of Coke, from which the Products of Distillation from the Coal, used in its Manufacture, have been Collected" (1885). (16) "Notes on the Reduction of Iron Ore in the Blast-furnace" (1887). (17) "On Gaseous Fuel" (1889). (18) "On the Probable Future of the Manufacture of Iron" (Pittsburg International Meeting, 1890). (19) "On the American Iron Trade and its Progress during Sixteen Years" (Special American Volume, 1890). (20) "On the Manufacture of Iron in its Relations with Agriculture" (1892). (21) "On the Waste of Heat, Past, Present, and Future, in Smelting Ores of Iron" (1893). (22) "On the Use of Caustic Lime in the Blast-furnace" (1894).

Sir Lowthian Bell took part in the first meeting of the Institute in 1869, and was present at nearly all the meetings up to May last, when he took part in the discussion on pyrometers, and on the synthesis of Bessemer steel. The state of his health would not, however, permit him to attend the American meeting, and he wrote to Sir James Kitson, Bart., Past-President, a letter expressing his regret. The letter, which was read at the dinner given by Mr. Burden to the Council in New York, was as follows:—

ROUNTON GRANGE, NORTHALLERTON,
12th October 1904.

MY DEAR SIR JAMES KITSON,—Four days ago I was under the knife of an occulist for the removal of a cataract on my right eye. Of course, at my advanced age, in deference to the convenience of others, as well as my own, I never entertained a hope of being able to accompany the members of the Iron and Steel Institute in their approaching visit to the United States.

You who knew the regard, indeed, I may, without any exaggeration, say the affection I entertain for my friends on the other side of the Atlantic, will fully appreciate the nature of my regrets in being compelled to abstain from enjoying an opportunity of once more greeting them.

Their number, alas, has been sadly curtailed since I first met them about thirty years ago, but this curtailment has only rendered me the more anxious again to press the hands of the few who still remain.

Reference to the records of the Iron and Steel Institute will show that I was one of its earliest promoters, and in that capacity I was anxious to extend its labours, and consequently its usefulness, to every part of the world where iron was made or even used; with this view, the Council of that body have always taken care to have members on the Board of Management from other nations, whenever they could secure their services. Necessarily the claims upon the time of the gentlemen filling the office of President are too urgent to hope of its being filled by any one not a resident in the United Kingdom. Fortunately, we have a gentleman, himself a born subject of the United Kingdom, who spends enough of his time in the land of his birth to undertake the duties of the position of Chief Officer of the Institute.

It is quite unnecessary for me to dwell at any length upon the admirable way in which Mr. Andrew Carnegie has up to this time

discharged the duties of his office, and I think I may take upon me to declare in the name of the Institute that the prosperity of the body runs no chance of suffering by his tenure of the Office of President.—
Yours faithfully, (Signed) LOWTHIAN BELL.

The funeral of Sir Lowthian Bell took place on December 23, at Rounton, in the presence of the members of his family, and of Sir James Kitson, Bart., M.P., past-president, and Sir David Dale, Bart., past-president. A memorial service was held simultaneously at the Parish Church, Middlesbrough, and was attended by large numbers from the North of England. A dense fog prevailed, but this did not prevent all classes from being represented. The Iron and Steel Institute was represented by Mr. W. Whitwell, past-president. Mr. J Riley, vice-president, Mr. A. Cooper and Mr. Illtyd Williams, members of council, Mr. H. Bauerman, hon. member, and the Secretary. The Dean of Durham delivered an address, in which he said that Sir Lowthian's life had been one of the strenuous exertion of great powers, full of bright activity, and he enjoyed such blessings as go with faithful, loyal work and intelligent grappling with difficult problems. From his birth at Newcastle, in 1816, to the present day, the world of labour, industry, and mechanical skill had been in constant flow and change. Never before had there been such a marvellous succession of advances, and in keeping pace with these changes Sir Lowthian might be described as the best scientific ironmaster in the world. He gave a lifelong denial to the statement that Englishmen can always "muddle through," for he based all his action and success on clearly ascertained knowledge.

The King conveyed to the family of the late Sir Lowthian Bell the expression of his sincere sympathy on the great loss which they have sustained. His Majesty was pleased to say that he had a great respect for Sir Lowthian Bell, and always looked upon him as a very distinguished man.

Immediately before the funeral an extraordinary meeting of council was held at the offices of Bell Brothers, Limited, Middlesbrough, when the following resolution was unanimously adopted:—

"The council of the Iron and Steel Institute desire to place on record their appreciation of the loss which the Institute has sustained by the death of Sir Lowthian Bell, Bart., a past-president and one of the founders of the Institute. The council feel that it would be difficult to overrate the services that Sir Lowthian rendered to the

Institute in the promotion of the objects for which it was formed, and his constant readiness to devote his time and energies to the advancement of these objects. His colleagues on the council also desire to assure his family of their most sincere sympathy in the loss that has befallen them." *

Alfred Henry Allen died on July 14, 1904, at his residence, in Sheffield. He was the son of Mr. George Allen, of Southwark, and was born in 1846. He studied at the Royal School of Mines, and subsequently went to Sheffield as assistant to Dr. James Allan, and on his death succeeded to his practice. In 1873 he was appointed public analyst by the Sheffield Corporation. Later he received the appointment of analyst for the West Riding of Yorkshire, as well as similar appointments in Barnsley and several other local boroughs. He was the author of the well-known work "Commercial Organic Analysis," and was a Fellow of the Chemical Society, a founder of the Institute of Chemistry, and a founder and past-president of the Society of Public Analysts. He contributed extensively to the various societies and institutions with which he was connected, and was the author of two papers on experiments on the existence of nitrogen in iron and steel, read before the Iron and Steel Institute in 1879 and 1880. He was elected a member in 1875.

Ernst Bertrand died at Kladno, in Bohemia, on October 7, 1904. Born in Silesia on December 5, 1847, he was the son of Carl Bertrand, of Lake Hopatcong, New Jersey. On the death of his father, he studied at the Hanover Polytechnic School. After a short period spent in sugar manufacture and railway construction in America, he became blast-furnace manager for Messrs. Moses Taylor & Franklyn. In 1873 he proceeded to Europe and succeeded Carl Wittgenstein at the Teplitz rolling-mills, of which works he eventually became head. At the time of his death he was director of the Kladno ironworks, and owned the greater portion of the shares of the company. He was elected a member of the Iron and Steel Institute in 1897, and in that year contributed to the proceedings a paper on the combined open-hearth process, invented by himself, in conjunction with Mr. O. Thiel.

Robert John Billinton died at his residence, Lea Hurst, Withdean, Brighton, on November 7, 1904, aged sixty years. He was a

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* Obituary notices and portraits of Sir Lowthian Bell are given in the *Engineer*, Dec. 23, 1904; in *Engineering*, Dec. 23, 1904; in the *Iron and Coal Trades Review*, Dec. 23, 1904; in *Ironmonger*, Dec. 24, 1904; in *Stahl und Eisen*, January 1, 1905, and in other journals.

native of Wakefield, and commenced his engineering career at the works of Sir William Fairbairn, Manchester, and was later at the London office of the late Mr. James Simpson. In 1871, after leaving the Yorkshire Railway works, he took charge of the drawing office of the London, Brighton, & South Coast Railway Co., and after four years' service left to become chief draughtsman to the Midland Railway Co. at Derby. In 1889 he returned to the Brighton Company as locomotive, carriage, wagon, and marine engineer. He was exceedingly popular, both with his directors and with his staff, his genial disposition rendering his relations with those with whom he came in contact most agreeable. He was a member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers. He was elected a member of the Iron and Steel Institute in 1893.

Frederick Brightmore died at his residence in Doncaster, on November 18, 1904. He took a prominent place in the affairs of his native town, having been twice Mayor of Doncaster (1894, 1895). He was an alderman of the town, a Justice of the Peace, and one of the original members of the Race Hunt Committee. At the close of the September meeting, of which he was chairman, he was presented with a diamond pin by the King. He was chairman of the Orient Steam Fishing Company, of Grimsby, of the Orient Coal Syndicate Company, of Grimsby, and of the Doncaster Steam Laundry Company, and was on the directorate of the Midland Iron Company, Limited. He was elected a member of the Iron and Steel Institute in 1904.

Joseph Charters Brown died at his residence at Cleator, near Carnforth, on December 14, 1904. He was largely interested in iron ore mining in West Cumberland, and in coal mining in the Rhondda Valley, South Wales. He was elected a member of the Iron and Steel Institute in 1874.

Leonard Cooper died on May 29, 1904, at his residence in Park Drive, Harrogate. He occupied a prominent position in the iron and steel trades of the North of England, and was agent for Yorkshire and Lancashire for the Leeds Steelworks Company. He was a large importer of Continental iron ores, and was on the board of the West Yorkshire Colliery Company, and managing director of the Cooper Patent Anchor Company. He was elected a member of the Iron and Steel Institute in 1880.

Charles Crookes died on September 22, 1904, at his residence in Sheffield. He was sixty-eight years of age, and was head of the firm of Crookes, Roberts & Co., steel converters and refiners, and manufacturers of engineers' tools, of the Argus Works, Shoreham Street, Sheffield. He was a member of the Sheffield Chamber of Commerce, and a prominent citizen. He was elected a member of the Iron and Steel Institute in 1902.

Hezekiah David, of Pencoed, died at Bath, where he had been staying for his health, on May 31, 1904, at the age of fifty-five. He was the son of the late Mr. William David, founder of the Pencoed foundry. He was a man who was held in high esteem by those who had business and other relations with him, and was exceedingly popular with his employés. He was elected a member of the Iron and Steel Institute in 1901.

Thomas Messinger Drown, President of Lehigh University, died on November 16, 1904, at South Bethlehem, Pennsylvania, after having undergone a surgical operation. He was born on March 19, 1842, and was educated at the Philadelphia Central High School, where he graduated in 1859. He then took up the study of medicine, and three years later received the degree of M.D. from the University of Pennsylvania. After a brief period of practice as a physician he turned to chemistry as his life work. Three years were spent in Germany in the study of chemistry and metallurgy, partly at the School of Mines at Freiberg and partly under Professor Bunsen at Heidelberg. He subsequently established himself as an analytical chemist at Philadelphia, and removed in 1874 to Easton, Pennsylvania, to become Professor of Chemistry at Lafayette College, where he remained for seven years. In 1873 he was elected Secretary of the American Institute of Mining Engineers, and retained that position by unanimous re-election until he resigned it in 1883. When he resigned his chair at Lafayette it was to enter upon private practice as a chemist. This work went on for five years, and in 1887 he became Professor of Chemistry at the Massachusetts Institute of Technology, whence he proceeded to Lehigh University in 1895. He was appointed in 1890 a member of an international committee to devise standard methods for the chemical analysis of iron and steel, and he personally made analyses to aid the discussion on this subject. In recognition of these labours, and of his services to the American Institute of Mining Engineers, he was elected in 1884 one of its honorary members, and in February 1897 he was made its President. The degree of Doctor of Laws was conferred upon him by Columbia University in June 1895. He was elected an honorary member of the Berzelius Society of the Sheffield Scientific School of Yale University. He was elected a member of the Iron and Steel Institute in 1886.

Otto Carl Ludwig Eichhoff died at his residence at Sayn, Germany, on September 30, 1904. He was educated at Cologne, passing his final examination in 1859. After a year's practical experience in the Siegen iron ore mines, he studied at the Universities of Bonn and Berlin, and at the mining colleges of Berlin and Freiberg in Saxony. His first appointment was as mining engineer at Wandre in Belgium. From April 1, 1868, he was occupied at Sayn with the general administration of the iron ore mines of Friedrich Krupp. He was subsequently a director of the Krupp firm, an office which he held until his death. He was also a member of the board of directors of the Orconera Iron Ore Company, Ltd., having been one of the original directors appointed in 1873. Of this company he was of late years managing director. He was a member of the Coblentz Chamber of Commerce from 1894 until his death. He was elected a member of the Iron and Steel Institute in 1893. In 1902 he attended the London meeting at the request of his cousin, His Excellency F. A. Krupp, to receive from the President the Bessemer Gold Medal awarded to that eminent ironmaster, a presentation which he acknowledged in most graceful terms.

Herbert Le Neve Foster, of Temple Row, Birmingham, died in the train on November 16, 1904, on his way home to his residence at Hamstead, near Birmingham. He was about fifty-three years of age. He was a son of the late Mr. Peter Le Neve Foster, Secretary of the Society of Arts, and a brother of the late Sir Clement Le Neve Foster. He was associated with Messrs. Thomas & Gilchrist in the introduction of the basic process, and was for some time manager of the Round Oak Steelworks. He was a skilled metallurgist, and manager of the Pwthwyllan Quarries, at Ruabon. He was an active member of the Iron and Steel Institute, to which he contributed, in 1888, a paper on a new instrument for colour determinations of carbon in steel. He was elected a member of the Iron and Steel Institute in 1880.

Henry Fownes died in Jarrow in August 1904. He was the founder and managing director of the Fownes Forge and Engineering Company, Limited. He was born in Liverpool, and was well known in shipping and engineering circles. He was for many years associated with John Spencer & Sons, Ltd., Newburn-on-Tyne. About six years before his death he started the St. Bede's works, East Jarrow, of which he was managing director. He was a member of the North-East Coast Institution of Engineers and Shipbuilders. He was elected a member of the Iron and Steel Institute in 1884.

James Hodgson, of Britton Place, Ulverston, died in July 1904. He was at one time President of the Barrow Chamber of Commerce, and was a Justice of the Peace and a director of the North Lonsdale Iron and Steel Company. For over thirty years he acted as colliery agent to the Wigan Coal and Iron Company. He was elected a member of the Iron and Steel Institute in 1893, and was a member of the Reception Committee on the occasion of the Barrow meeting in 1903.

Charles James Pascoe Jennings died, in September 1904, in British Guiana. He had for some years been connected with iron ore mining in the north of Spain, and from 1890 to 1895 he was blast-furnace manager at the works of Messrs. Palmer & Co., Jarrow. After leaving this firm he entered into partnership with a firm of engineers in London; but, soon after, he retired. Early this year, however, he resumed business, and travelled to Demerara and commenced operations as a cotton planter. He was elected a member of the Iron and Steel Institute in 1882.

Herbert Kirkhouse died at his residence at Pontsticill, near Merthyr, on September 3, 1904, at the age of seventy-two. He was a well-known Welsh mining engineer, who had been prominently connected during the past half-century with the development of the mining industry in the Aberdare and Rhondda valleys. He came of a well-known Merthyr family, formerly connected with the Cyfartha Works, Dowlais. Though more especially remembered in association with the Hirwain and Tylorstown Collieries, he had a great reputation as an advisory engineer throughout the South Wales coalfield. He was also connected with the slate industries of North Wales and Pembrokeshire. He was a magistrate for the counties of Glamorgan and Brecknock, a member of the Brecon County Council, and a Fellow of the Geological Society of London, and a past-president of the South Wales Institute of Engineers. He was elected a member of the Iron and Steel Institute in 1899.

Henry Lee, a life director of the Tootal Broadhurst Lee Co., Limited, cotton spinners and manufacturers, of Manchester, died on December 27, 1904, at his residence in Salford, aged eighty-seven. Until the last he had continued to take an active part in the management of the firm. He was associated with Cobden and Bright in the agitation for the repeal of the Corn Laws. In 1880 he was returned as senior Liberal member for Southampton, but lost his seat at the election five years later. In 1886 he contested North-west Manchester against Sir William Houldsworth, M.P., but was defeated. He had been president of the Manchester Chamber of Commerce. He was a director, and formerly chairman, of Bolckow, Vaughan & Co., Limited, and a director of Williams Deacon's Bank, Limited. He was elected a member of the Iron and Steel Institute in 1889.

John Fulton Miller died at his residence, Greenoakhill, Mount Vernon, Lanarkshire, on November 18, 1904. He was born in Crossmyloof in 1848. Choosing engineering for his vocation, he served his apprenticeship with J. & G. Thomson, afterwards of Clydebank, in the old Clydebank Engineering Works, Finnieston Street, and in the Govan shipyard of that world-famed firm. In 1870 he became a partner in his father's firm of James Miller & Company, rivet, bolt, and nut manufacturers. On the conversion of that firm into the Rivet, Bolt, and Nut Company, Ltd., in 1895, and the transference of the works to Coatbridge, he was appointed chairman, and continued to hold that position until his death. He was also senior partner of George Miller & Sons, coalmasters, and for ten years previous to 1892 he was managing partner to the engineering works of Miller & Company, in Coatbridge. He was a Justice of the Peace for the county of the city of Glasgow and for Lanarkshire, and a director of many commercial and benevolent institutions of the city. He was elected a member of the Iron and Steel Institute in 1882, and was a member of the Local Reception Committee in Glasgow, upon the occasion of the visit of the Iron and Steel Institute to that city in 1901.

William Ford Smith, the founder and chairman of Smith and Coventry Ltd., of Salford, died in October, 1904, at his residence in

Manchester, in his seventy-fourth year. Born at Bath, on February 1, 1830, the son of an engineer who conducted the works now carried on under the style of Siddeley & Co., he received his training as an engineer at the Collegiate Institution of Liverpool. After his collegiate course he spent a year at the locomotive and marine engineering works of Bury, Curtis & Kennedy, of Liverpool, proceeding thence to take up a position of responsibility at his father's works. When nineteen years of age he joined the staff of the Shrewsbury & Chester Railway workshops, continuing there for over two years, when he became attached to the firm of Sharp, Roberts & Co., which then, as through subsequent variations of title, was one of the foremost locomotive-building concerns in the country. In the early fifties he began business for himself, first at the Bonding Warehouse, Chapel Street, Salford, and a year later was joined by Mr. Arthur Coventry. The works of the company at Ordsal Lane, Salford, were designed and constructed under the supervision of Mr. Ford Smith in 1859. He was a member of the Institution of Mechanical Engineers. He was elected a member of the Iron and Steel Institute in 1877.

Sir James Steel, Bart., a former Lord Provost of Edinburgh, died in that city on September 4, 1904. He was born in 1830, and was the son of the late Mr. James Steel, of Summerside Mains, Cambusnethan. About thirty-eight years ago he began business in Edinburgh as a builder, and during his business career he was associated with the erection of some of the principal buildings in Edinburgh. In 1872 he entered the town council, and after serving as a magistrate for some years he was elected in 1900 Lord Provost. He held this office when, in 1903, the King made his first visit to Scotland after his Coronation, and it was on that occasion that his Majesty conferred a baronetcy upon him. He was chairman of Niddrie and Benhar Coal Co., Ltd., large producers of coal and iron ore, and of the Broxburn Oil Co., Ltd., and vice-chairman of the National Insurance Co., Ltd. He was elected a member of the Iron and Steel Institute in 1890.

Harry Worton, manager of the Ebbw Vale Steel and Ironworks, died on July 19, 1904. He was an able engineer, and had long been connected with Messrs. Crawshay Brothers of Cyfarthfa. He was elected a member of the Iron and Steel Institute in 1897.

MEMORIAL TO PETER VON TUNNER

THE eminent Austrian metallurgist, Peter von Tunner, Honorary Member and Bessemer Gold Medallist of the Iron and Steel Institute, died at Leoben, in Styria, on June 8, 1897. Shortly after his death, steps were taken to organise a suitable memorial. The sum collected for the purpose of erecting at Leoben a statue to him amounted to 27,206 Austrian crowns, of which 1303 crowns were subscribed by members of council of the Iron and Steel Institute. The chairman of the committee was Mr. Prandstetter, and the committee included R. Åkerman, Sir Lowthian Bell, A. Greiner, H. M. Howe, C. Lueg, J. Massenez, E. Schroedter, and H. Wedding. The monument was unveiled on November 29, 1904, in the presence of a large gathering of distinguished guests, of professors and students of the Leoben School of Mines, and of miners and smelters in picturesque uniforms. The band of the 7th Infantry Regiment and a military guard of honour were in attendance, and the town was decorated with flags. The proceedings were opened by Mr. Prandstetter, chairman of the Memorial Committee, who welcomed the guests, specially thanking for their presence His Excellency the Minister of Agriculture (Count Buquoy), His Excellency the Governor of Styria (Count Clary), His Excellency the Landeshauptmann of Styria (Count Attems), the members of the von Tunner family, the professors of the Leoben School of Mines, the representatives of the various associations and corporations. He described the steps that had been taken to organise the memorial, and stated that of the ten designs submitted by five sculptors, that prepared by the Viennese artist, Karl Hackstock, had been chosen. He then called upon Professor von Ehrenwerth, as pupil and successor of Tunner in the Chair of Metallurgy at the Leoben School of Mines, to unveil the monument.

Professor von Ehrenwerth then, in an eloquent speech, gave a brief history of the Leoben School of Mines, in which Tunner was the first teacher. The Styrian School of Mines was, he said, founded in 1836, and Peter Tunner, who was then Prince Schwarzenberg's agent in the steel forge at Katsch, was chosen as teacher. Born on May 10, 1809, at Deutsch-Feistritz, he was from his youth engaged in his father's occupation of mining and smelting. On the completion of his studies at Vienna (1828–1830), he returned home to his post at Katsch. In a speech in Parliament, the Archduke John stated that after careful investigation he recommended Peter Tunner for the appointment of Professor of Metallurgy. A native of the district, of the highest moral character, one of the best students of the Polytechnic Institute, thoroughly equipped with the necessary scientific knowledge, fully experienced in the local treatment of iron, and of good presence, he fulfilled all the requirements for the post. The Archduke further recommended that funds should be voted to enable Tunner to make an educational journey through Silesia, Sweden, and other countries. On November 4, 1836, the new mining school was opened, and here Tunner instructed the students in practical work. In 1849 the school was moved to Leoben. In July, 1866, Tunner resigned his professorship, and in 1874 the directorship of the school. His book on hearth fining was the first original work of the kind. That on roll-turning was, until 1870, the only scientific treatise on the subject. He followed all inventions in connection with iron and steel. His researches on the blast-furnace process were based on direct experiments, and the introduction of the Bessemer process into Austria was due to his energy. Tunner's merits were widely and worthily recognised. The crosses of eight Orders of Knighthood decorated his breast. He was a privy councillor, a Bessemer Gold Medallist, and an Honorary Member of the Iron and Steel Institute, of the American Institute of Mining Engineers, of the Philosophical Society of Philadelphia, and of the Royal Academy of Sciences of Stockholm. He was Honorary President of the Mining Society of Styria, and Honorary Freeman of the towns of Leoben, Vordernberg, Eisenerz, Hüttenberg, Bleiberg, and Raibl. With good reason have his pupils and admirers from far and near gladly co-operated to erect to the master a worthy memorial, of oldest rock from the Sweden that was dear to him, and from his own green land of Styria, and of lasting metal, shaped by a native artist hand.

Mr. Prandstetter then asked the Mayor of Leoben to receive the monument, and to maintain it in honour of one who has done much for his native town of Leoben. Dr. Grübler, the Mayor, having accepted the monument in the name of the corporation, as a sacred trust, the guests present proceeded to lay wreaths on the base.

The memorial is a work of great artistic merit. On a base of Swedish granite is placed the monument of Bacher granite, bearing a life-size bronze bust of Tunner. To the left stands the bronze figure of a mining student, as symbolic of science, and, to the right, the bronze figure of a smelter, as symbolic of labour. The figures are winding round the monument a wreath of laurel and oak.

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"Mining in British Columbia." Official Bulletin, No. 19. 8vo, pp. 176. Victoria, B.C. 1904.	The Agent-General.
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"Report of the Commission appointed to Investigate the different Electro-Thermic Processes for the Smelting of Iron Ores and the making of Steel in operation in Europe." Ottawa. 1904.	The Superintendent of Mines.
"Commercial Pig Irons." By E. Adamson. (Lecture before the Sheffield Society of Engineers and Metallurgists, November 30, 1903.)	The Author.

INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions:—

LONDON.

Board of Trade.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution.
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

PROVINCIAL.

Birmingham University.
Cleveland Institution of Engineers.
Engineering Society (Leeds).
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Manchester Association of Engineers.
Manchester Geological and Mining Society.
Merchant Venturers' Technical College (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining and Mechanical Engineers.
Royal Dublin Society.
Sheffield Technical School.
South Staffordshire Iron and Steel Institute.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
University College of South Wales.
West of Scotland Iron and Steel Institute.

COLONIAL AND FOREIGN.

Colonial.

Australasian Institute of Mining Engineers.
Canadian Institute.
Canadian Mining Institute.
Canadian Society of Civil Engineers.
Department of Mines, Melbourne.
Department of Mines, Sydney.
Geological Survey of Canada.
Geological Survey of India.
Geological Survey of New South Wales.
Mining Society of Nova Scotia.
Royal Society of New South Wales.

United States.

American Association for the Advancement of Science.
American Foundrymen's Association.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Department of Labour.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
Massachusetts Institute of Technology.
New York Academy of Sciences.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institution.
United States Geological Survey.

Austria.

K.K. geologische Reichsanstalt.
Oesterr. Ingenieur- und Architekten-Verein.

Belgium.

Association des Ingénieurs sortis de l'École des Mines de Liége.
Ministère de l'Intérieur.

France.

Comité des Forges.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

Denmark.

Tekniske Foreningen.

Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

Italy.

Reale Accademia dei Lincei.

Sweden.

Geological Institution of the University of Upsala.
Jernkontoret.

JOURNALS.

The following periodicals have been presented by their respective Editors :—

UNITED KINGDOM.

"Automobile Club Journal."
"British Fire Prevention Committee."
"Coal and Iron."
"Colliery Guardian."
"Contract Journal."
"Electrical Engineer."
"Electrician."
"Electro-Chemist and Metallurgist."
"Engineer."
"Engineer and Iron Trades Advertiser."
"Engineering."
"Engineering Press Monthly Index Review."
"Engineering Review."
"Hardware Trade Journal."
"Hardwareman."
"Horological Journal."
"Iron and Coal Trades Review."
"Iron and Steel Trades Journal."
"Iron Trade Circular."
"Ironmonger."
"London Technical Education Gazette.'
"Machinery Market."
"Marine Engineer."
"Mechanical Engineer."
"Navy League Journal."
"Page's Weekly."
"Petroleum Review."
"Phillips' Monthly Register."
"Plumber and Decorator."
"Practical Engineer."
"Public Works."
"Quarry."
"Railway World."
"Science and Art of Mining."
"Shipping World."
"Statist."
"Tool and Machinery Register."
"Vulcan."

COLONIAL AND FOREIGN.

Colonial.

"Canadian Mining Review."
"Indian Engineering."

United States.

"American Journal of Science."
"American Machinist."
"American Manufacturer."
"Bradstreet's."
"Cassier's Magazine."
"Engineering and Mining Journal."
"Engineering Magazine."
"Engineering News."
"Iron Age."
"Iron and Steel Magazine."
"Iron Trade Review."
"Machinery."
"Mines and Minerals."
"Mining Magazine."
"Railroad Gazette."

Austria.

"Oesterr. Zeitschrift für Berg- und Hüttenwesen."

Belgium.

"Bulletin de l'Union des Charbonnages de Liége."
"Moniteur des Intérêts Matériels."
"Revue Universelle des Mines."

France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Le Mois Scientifique et Industriel."
"Portefeuille Économique."

Germany.

"Annalen für Gewerbe und Bauwesen."
"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen- und Stahl Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
"Zeitschrift für praktische Geologie."
"Zeitschrift für Werkzeugmaschinen und Werkzeuge."

Italy.

"L'Industria."
"Rassegna Mineraria."

Peru.

"Cuerpo de Ingenieros de Minas."

Spain.

"Revista Minera."

Sweden.

"Teknisk Tidskrift."

SECTION II.

NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

CONTENTS.

In the preparation of these Notes the Editor has been assisted by E. J. BALL, Ph.D., Assoc. R.S.M., and H. G. GRAVES, Assoc. R.S.M.

IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

Formation of Ore Deposits.—P. Frazer* discusses geogenesis and some of its bearings on economic geology.

The theory of ore deposits is discussed by E. B. Wilson †

The distribution of the chemical elements in the earth's crust has been studied by L. de Launay.‡

Artificial Formation of Magnetite.—J. Donau § has made experiments in which pure iron wire was heated at 1200° C. in a current of dry carbon dioxide. They showed that the product is ferroso-ferric oxide, which resembles natural magnetite in appearance, crystalline form, density, hardness, &c. The product is magnetic, and the crystals often show magnetic polarity, especially when the heating has been carried out in an electric furnace. The presence of moisture in the carbon dioxide has no influence on the result, except that the formation of large crystals is facilitated.

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* *Transactions of the American Institute of Mining Engineers*, February 1904.

† *Mines and Minerals*, vol. xxiv. pp. 527–529.

‡ *Revue générale des Sciences*, vol. xv. pp. 386–404.

§ *Monatshefte*, vol. xxv. pp. 181–187.

Iron Ore in Austria.—The magnetite deposits at Maleschau and Hammerstadt in Bohemia are described by F. Katzer.*

The occurrence of iron ore at Kohlbach on the Stubalp, Styria, is described by R. Canaval.†

The chamoisite bed at Nucic, near Prague, is described by R. d'Andrimont.‡

K. A. Redlich § discusses the age and origin of some iron ore and magnesite deposits of the Styrian Alps.

C. von John || and C. F. Eichleiter give analyses of brown iron ore from Kleinzell in Lower Austria (43·62 per cent. of iron), of red hæmatite from the same locality (44·32 per cent. of iron), of specular iron ore from the Stubaithal in Tyrol (30·04 per cent. of iron), of red hæmatite from Rudo in Croatia (67·28 per cent. of iron), of limonite from Trebitsch in Moravia (47·71 per cent. of iron), and of brown iron ore from Thal near Graz (48·75 per cent. of iron).

Iron Ore in Bosnia.—The geology of the Liassic iron ore bed at Vares in Bosnia is described by H. Beck. ¶

C. von John ** and C. F. Eichleiter give the following analysis of red hæmatite from Buki in Bosnia :—

Fe_2O_3.	MnO.	Al_2O_3.	CaO.	MgO.	SiO_2.	P.	Loss on Ignition.
66·90	0·51	0·22	2·26	0·20	28·24	0·014	1·30

Iron Ore in Greece.—In a consular report, W. H. Cottrell †† gives particulars of the iron ore deposits of the Cyclades. At Syra there are two mines near the seashore, the ore yielding 44·10 per cent. of iron, 2·23 per cent. of manganese, 0·04 per cent. of phosphorus, 7·16 per cent. of silica, and 2·23 per cent. of moisture.

The chief iron deposits of Seriphos occur in the limestone on the west part of the island; in the centre and south-east coast some small veins of magnetite are found in an eclogitic state. Five good harbours, accommodating the largest steamers in this particular trade, facilitates

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* *Verhandlungen der k.k. geologischen Reichsanstalt*, 1904, pp. 193–200.

† "Bergbaue Steiermarks," by K. A. Redlich, part v., 14 pp. Leoben, 1904.

‡ *Annales de la Société géologique de Belgique*, vol. xxx. pp. 123–124.

§ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 285–294.

|| *Ibid.*, pp. 499–501.

¶ *Ibid.*, pp. 473–480.

** *Ibid.*, p. 499.

†† *Mining Journal*, vol. lxxv. p. 661.

the export. The cost of mining, transporting, and loading on board is 3s. 9d. per ton. The analysis is given as follows:—

	Brown Ore. Per Cent.	Red Ore. Per Cent.
Iron	52·19	47·05
Manganese	0·58	2·72
Lime	1·16	6·73
Silica	6·27	4·22
Sulphur	0·18	0·12
Phosphorus	0·04	0·02

There are several iron ore deposits in Zea, situated at Cape Spathi and Petrussa. The commercial port of St. Nikolo is only distant from nine to fourteen miles, but of no avail to the mines as there are no means of transport thither. Shipments are effected on the spot near the deposits, by means of a Decauville portable railroad and trucks, at about 3s. per ton. The ore yielded:—

	Spathi. Per Cent.	Petrussa. Per Cent.
Iron	48·93	50·69
Manganese	22·05	2·12
Silica	3·70	7·10
Zinc	...	1·50

The analyses of Oreos and Schino mines are not obtainable, but the yield is reported to be 55 to 65 per cent. of iron. Little work is being done at present on the Spathi, Oreos, and Petrussa mines, owing to lack of capital and scarcity of ore, and at Schino the work is so far in an experimental stage. During 1903 only 1500 tons of ore were exported from these mines, most of which went to Glasgow.

Three iron ore deposits exist in Thermia, two of which are situated close to the port of St. Stephen and the third close to the port of Irene, about 500 yards distant. The ore is conveyed to the seashore from two of the mines by means of a portable railway and trucks, thence by shoots direct into the ships. In the other case an aerial line is employed. The total cost of mining, transport, and loading is 3s. 9d. per ton. Analysis yields:—

		Per Cent.		Per Cent.
Iron	From	44·50	to	48·00
Manganese	,,	1·50	,,	2·00
Silica	,,	8·00	,,	11·00
Phosphorus	,,	0·025	,,	0·03
Sulphur	,,	0·06	,,	0·10
Arsenic	,,	0·07	,,	0·12
Lime	,,	0·04	,,	0·07

Iron Ore in Russia.—In a consular report, A. G. Brophy * states that the chief iron ore deposits in the south of Russia are near Kertch, those in the Don Cossack territory, and those of the Krivoi Rog, but only a small extent of the latter belongs to the Ekaterinoslav province in this consular district, the rest lying just outside the borders.

The Donetz field is the least extensive, and the ore, holding about 40 to 45 per cent. iron, occurs mostly in pockets, making the working very uncertain. The Kertch deposits are the largest, the latest corrected estimate pointing to 846,000,000 tons. They are only a few miles distant from the port of that name, are near the surface, and easily worked and smelted, but the quality is inferior, 30 to 40 per cent. of iron, with 10 to 20 per cent. silica, and 1 to 2 per cent. of phosphorus, necessitating special treatment.

The Krivoi Rog ore is the richest, containing from 45 to 65 per cent. iron, but owing to the slackness in the home Russian market for metals, the best class ore has begun to be exported. In 1902 only 32,000 tons were thus disposed of, but during the year just past the figures amounted to 290,000 tons, half going by rail to Silesia and the other half to Nicolaieff for shipment abroad. Some authorities deplore the temporary necessity of sending abroad their best ore, saying that if the system were to be continued it would ruin the Russian iron industry. The argument is that to obtain good workable cast iron it is necessary to smelt the poorer ores with a certain proportion of the richer; for example, 9 parts (by volume) Kertch ore, 3 parts of Donetz, and 2 parts of Krivoi Rog, taking the relative percentage of iron to be 40, 45, and 60 per cent.; or else, Krivoi Rog one-third at 60 per cent., and Kertch two-thirds at 30 per cent. The quantity of the known deposits of rich, 60 per cent. Krivoi Rog iron ore is calculated at about 56,000,000 tons, which, at the present slack rate of working, would last for twenty years; but if the local demand were to spring up again, it would all be exhausted in ten years.

L. Podgajetzky † describes the iron ore mines which are situate in the Kertch peninsula, at a distance of about seventeen miles from the town of Kertch and a mile and a quarter from the sea. The ore mined is an oolitic brown iron ore embedded in Tertiary deposits. It crops out and is easily mined. Altogether it is estimated that the property contains at least 12,300,000 tons of ore

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* *Mining Journal*, vol. lxxv. p. 659.

† *Gornosavodsky Listok*, May 1904; *Stahl und Eisen*, vol. xxiv. pp. 1010–1012.

with not less than 37 per cent. of iron. The bed of ore is from about 30 to 50 feet in thickness, and the ore it contains can be divided into black, brown, and light brown ores. The two former comprise the bulk of the deposit, and their chemical composition is found to be as follows, little difference being noticeable between the two :—

Iron.	Manganese.	Phosphorus.	Silica.
38 to 42	2 to 4	about 1·0	about 17·0

The sulphur does not exceed 0·05 per cent.

The light brown ore is richer in iron and poorer in manganese. The iron contents reaches 44 per cent., and the manganese rarely exceeds 1 per cent., while it is often much less. It forms the bottom layer of the ore deposits, and is about 6 feet thick; many large lumps of hard brown iron ore are found in it. The first cost of the ore is about 5s. 6d. per ton on a yield of 132,000 tons of ore per year. Details as to this cost are given. It is anticipated that it will prove possible to reduce it to about 4s. per ton. In their natural condition the Kertch iron ores are granular and hygroscopic. In the freshly mined ore the moisture averaged 12 per cent. In rainy weather it may rise to 22 per cent., while it may be as little as 6 per cent. if the weather is very dry. This variable composition renders it necessary to briquette the ore to obtain a material free from moisture and higher in iron. These ores are found to be well suited for this treatment. It contains about 8 per cent. of clayey constituents and can be calcined and briquetted without any addition of foreign binding agents. Crude petroleum is used as the fuel for this purpose. An analysis of the ore briquettes shows:—

Fe.	Mn.	P.	S.	SiO_2.	Al_2O_3.	CaO.	MgO.	BaO.	Alkalies.
45·61	3·73	0·93	0·13	17·37	5·62	1·90	1·02	0·62	0·68

It is proposed to reduce the ore on the spot.

Iron Ore in Turkey.—The actual position of the iron industry of Turkey is briefly dealt with,* reference being made to official reports.† There appears at present to be no real iron industry in Turkey at all. Iron ores are frequently met with, Asiatic Turkey especially being rich. Coal, too, is found in many places, but in only a few of them does it appear to exist in any quantities. The most important of the coalfields appear to be those near Mandjilik in the Brussa province, near Erzerum, and in Heraklea. Im-

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* *Stahl und Eisen*, vol. xxiv. pp. 923-924.

† *Berichte über Handel und Industrie*, vol. vi. p. 767.

portant iron ore deposits are found in the region of the Euphrates, and others also at no great distance from Brussa. None of these, however, are mined on any important scale. The iron industry of Turkey, such as it is, consists chiefly in the working up of imported iron in small forges into small articles of everyday use.

Iron Ore in Scandinavia.—W. F. Wilkinson * reviews the iron ore industry in Sweden and Norway, giving some account of the work done in Dunderland, Kiiruna, and Gellivara.

Hecker † describes the iron ore deposits of Gellivara, Kiirunavaara, and Luossavaara, and the equipment of the Ofoten railway.

The iron ore deposits of Arctic Lapland are also described by C. S. Osborn. ‡

In a paper read by Lund § before the Norwegian Society of Engineers and Architects, he describes the iron ore deposits at Varanger. They were only discovered in the summer of 1902. They occur along the south coast of the Varanger Fiord in lat. 69° 40′, in north-east Norway, close to the Russian frontier. The ore occurs in a grey gneiss-like rock in an extensive granite district. It is fairly hard, strongly magnetic, and has a specific gravity of 3·6. It occurs in two forms, being associated with hornblende in one form and with quartz in the other. The strike is chiefly NNW., and the dip is as much as 70°. The ore district is about 10 miles long and about 3·7 miles wide, and is consequently about the second largest in the country as regards surface area. The various seams occur at about 350 feet above sea-level. They are of considerable length, and vary in thicknes from 1 to 160 yards, the available ore being estimated at 350,000,000 tons. The percentage of iron varies from 30 to 58, the average being probably about 38. The ore contains 0·04 per cent. of phosphorus, 0·013 of sulphur, 0·14 of titanic acid, and 0·3 of manganese, together with silica varying in quantity up to 40 per cent. The position is very favourable, water transit being available in parts, while a railway of 5 miles in length, from a harbour near Kirkenes, would tap the main deposit. By magnetic treatment the iron can be raised to between 58 and 65 per cent., and the phosphorus reduced to 0·01.

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* Paper read before the Institution of Mining and Metallurgy, June 16, 1904.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 61–85.

‡ *Journal of the Lake Superior Mining Institute*, vol. ix. p. 94.

§ *Teknisk Ugeblad*, 1904, pp. 127–128.

G. Henriksen* describes the deposit at Sydvaranger in Finnmarken. It consists of a series of superimposed beds of magnetite, hornblende, and quartz, but, as the iron in the hornblende would probably pass into the slag in the furnace, or be lost in the concentration processes, it need not be taken into consideration. The author considers the ore deposits to be due to decomposition of the gabbro, which exists in large quantities, together with grey gneiss and other rocks. Where the decomposition was less, or where the gabbro was poorer in iron, as a rule only quartz and hornblende have been formed. The amount of iron in the deposit consequently varies enormously. The ore is present in considerable quantities, the author calculating this at from 50,000,000 to 100,000,000 tons. A report on the deposits has been published in English.†

Iron Ore in Spain.—S. Thos y Codina ‡ describes the ore deposits of the Valle de Ribas in the Pyrenees. The iron ores met with include magnetic iron ore, specular iron ore, and spathic iron ore of excellent quality. These ores formerly were smelted in the various Catalan forges existing in the Pyrenees.

C. Schmidt § and H. Preiswerk describe the iron ore deposit at Cala in the Sierra del Venero, province of Huelva.

A. Gascon ‖ describes the iron ore deposits at Burguillos, Badajoz.

R. Guardiola ¶ deals with the mineral resources of the district of Cartagena.

Iron Ore in Switzerland.—A. Wencelius ** describes the Delsberg mines of the De Roll Ironworks. The ore is an oolitic iron ore containing 10·33 per cent. of silica, 45·20 per cent. of iron, 11·60 per cent. of alumina, 0·09 per cent. of phosphoric anhydride, and 0·18 per cent. of manganese, the loss on ignition being 13·16 per cent.

Iron Ore in India.—E. P. Martin †† and H. Louis have investigated the better known iron ore districts in Jabalpur district, Central

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 232.

† *The Iron Ore Deposits at Sydvaranger, Finnmarken, Norway, and relative Geological Problems.* 8vo, pp. 8.

‡ *Gaceta Minera de Cataluña*, vol. iv. p. 177.

§ *Zeitschrift für praktische Geologie*, vol. xii. pp. 225–232.

‖ *Boletin Minero*, vol. vii. p. 373.

¶ *Ibid.*, p. 225.

** *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 217.

†† *The Agricultural Ledger*, 1904, No. 3.

Provinces, and show that they are not suitable for modern methods of smelting. The particular deposits considered are the Agria Hill, Agria Ridge, Jauli, and Silondi-Mansukra. At all these places there is a scattered supply of ore suitable for native smelting even on a considerable scale, but the deposits are not sufficiently extensive nor persistent, and the ore must generally be hand picked. Analyses show up to 64 per cent. of iron in the best ore, but the phosphorus is generally above the Bessemer limit, and is rather too low for the basic process.

H. H. Hayden * reports that red hæmatite is found in the high range three miles south-west of Muth, forming a band about 3 feet thick among the Cambrian trilobite beds; but its total extent is small, and there is a complete absence of fuel.

Iron Ore in Canada.—An illustrated article has appeared,† dealing with the coal and iron ore resources of Canada, embodying information contained in a work on Canada's resources by J. S. Jeans.

Iron Ore in Western Australia.—D. Clark ‡ states that iron ores are widely distributed in Western Australia in association with crystalline schists and as surface deposits. A number of localities are specified, but at present the ores have only been worked as fluxes. Several of the deposits are of very considerable size.

Iron Ore in the Lake Superior Region.—In the Marquette region C. K. Leith § and W. N. Smith have determined the extent and nature of the unconformity at the base of the Ajibik quartzite in the Lower Huronian series. There are now discriminated there distinct unconformable series in the so-called Huronian of this district. The newly found occurrence of iron ore in the Baraboo ranges in Southern Wisconsin has been investigated by S. Weidman. ‖ The ore is mainly a Bessemer hæmatite. A very small amount of limonite is also present. The deposits are conformable with the associated stratified rocks. At the Illinois mine the deposit is 30 to 35 feet thick and contains 54 to 58 per cent. of iron.

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* *Memoirs of the Geological Survey of India*, vol. xxxvi. pp. 1-129; *The Geology of Spiti, with Parts of Bashahr and Rupshu.* London: Kegan Paul, Trench, Trübner, & Co. 5s. 4d.

† *Iron and Coal Trades Review*, vol. lxviii. pp. 1456-1464, 1491-1502.

‡ *West Australian Mining and Metallurgy*, 1904, pp. 199-200.

§ *United States Geological Survey, Bulletin* No. 225, p. 217.

‖ *Wisconsin Geological Survey, Bulletin* No. 13.

A considerable amount of exploration for iron ore in the Western Mesabi district has resulted in the discovery of further deposits of large size.*

A description is given † of some of the iron ore deposits of Lake Superior.

Iron Ore in Alabama.—At the Lookout Mountain in Alabama, a seam of fossiliferous red hæmatite, 4½ to 5½ feet in thickness, lies over a seam of coking coal 3 feet in thickness. Two other seams of coal and also two other seams of iron ore outcrop in the neighbourhood, and a thick seam of good limestone is also found. Both coal and ore are worked through inclines. An analysis of the ore shows 37 per cent. of iron.‡

Iron Ore in Alaska.—W. C. Mendenhall § and F. C. Schrader note the occurrence of magnetite in the Mount Wrangell district, Alaska.

Iron Ore in Montana.—F. W. Clarke ‖ gives the following analysis of magnetite from the Gallatin range, near Bozeman, Montana:—

Insol.	Fe_3O_4.	Al_2O_3	MnO.	MgO.	TiO_2.
0·16	96·70	0·04	0·93	0·07	2·71

with 0·012 per cent. of phosphoric anhydride and 0·171 per cent. of sulphur.

Iron Ore in Utah.—There has recently been a renewal of interest in the iron ore deposits of the Western United States, and two groups of deposits in Utah have been examined, one in the Uinta Mountains by J. M. Boutwell,¶ and one in southern Utah by C. K. Leith.** The ore of the Uinta range is a red hæmatite containing 79·34 per cent. of ferric oxide, 0·15 per cent. of alumina, 18·55 per cent. of silica, only a trace of phosphorus, and no sulphur, titanium, and lime. It occurs in limestone, probably in replacement deposits along east

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* *Iron Age*, June 2, 1904, pp. 34–35.

† *Iron and Coal Trades Review*, vol. lxix. pp. 1484–1486.

‡ *Iron Age*, August 4, 1904, pp. 27–29; *Iron Trade Review*, August 4, 1904, pp. 68–71.

§ *United States Geological Survey, Professional Paper* No. 15. Washington, 1903.

‖ *Ibid.*, *Bulletin* No. 220, p. 20.

¶ *Ibid.*, *Bulletin* No. 225, p. 221.

** *Ibid.*, p. 229.

and west fracture zones, in considerable but improved quantities. In southern Utah iron ore deposits occur along the slopes of a spur of the Wasatch Mountain, near the contact of andesite and limestone. The ore is specular iron ore and magnetite in varying proportions. Analyses show 46·7 to 67·9 per cent. of iron, and 0·029 to 1·134 per cent. of phosphorus. Much of the ore is of good quality, though, for the most part, non-Bessemer. It is believed that the ore is a secondary replacement and vein deposit, through the agency of percolating water, mainly along the contact of the andesite and limestone.

C. K. Leith[*] and O. Rohn describe the Iron Mountain district of southern Utah. The ore outcrops in lenticular deposits over an area about 18 miles in length and up to 2½ miles in width, between andesite and limestone. It is hæmatite and magnetite. An average analysis shows:—

Fe.	SiO_2.	S.	P.	Mn.	CaO.	MgO.	Ca.
58·54	8·29	0·082	0·185	0·118	2·71	1·77	0·027

but in one series of analyses the iron ranges from 46 to 68 per cent., and the phosphorus from 0·029 to 1·134 per cent.

F. Lerch[†] also deals with the iron ores of southern Utah, including the Iron Mountain and the Iron Springs deposits.

E. P. Jennings[‡] discusses the origin of the magnetic iron ores of Iron county, Utah.

Iron Ore in Algeria.—The occurrence of iron ore in the province of Constantine is described by R. Chudeau.[§]

Iron Ore in the Soudan.—In a recent American consular report[||] it is stated that iron ore has been found in Kordofan, in the Bahr-el-Ghazal, in Darfur, and on the Abyssinian frontier. In Kordofan two deposits have been found, the ore being brown hæmatite, occurring in fragments at a shallow depth in the sand. It probably occurs in considerable quantities, but there is no fuel near, and no materials from which furnaces could be constructed. Railway communication would be necessary to make it of any commercial advantage. Small quantities are worked up by the

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[*] *United States Geological Survey; Iron Age*, April 21, 1904, p. 22.
[†] *Iron Trade Review*, May 19, 1904, pp. 49–50.
[‡] *Transactions of the American Institute of Mining Engineers*, February 1904.
[§] *Revue générale des Sciences*, vol. xv. p. 703.
[||] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 275.

natives. Other deposits are also mentioned. In the district of Zur the bulk of the natives are smiths and produce excellent iron.

Iron Ore in China.—W. H. Shockley * gives some notes on the coal and iron ore fields of south-eastern Shansi in China. The general topography and geology of the district is described, and some details are given of various producing localities. A few analyses are given and some details of the native manufacture.

It is stated that rich deposits of iron ore have been discovered in China at a distance of about 40 miles from Hanoi. At no great distance from them are deposits of anthracite, which are now being mined. When mixed with the bituminous coals of Japan or Yunnan a serviceable coke can be produced.†

C. E. Heurteau ‡ states that important contracts have been entered into by the Hanyang works to supply hæmatite ores from Tayeh (Houpé) for use at the Wakamatsu works in Japan. The ore, which contains about 65 per cent. of iron, is conveyed to Japan by three special steamers, at a rate of 50,000 tons per annum.

Iron Ore in Japan.—C. E. Heurteau,§ in an article on the imperial ironworks of Wakamatsu, Kiushiu, describes the workings from which the ores are derived. The Kamaichi mines which yielded a magnetite, containing, after calcination, 63 per cent. of iron, being almost exhausted, concessions have been acquired at Akadani, where a hæmatite containing 64 per cent. of iron is obtained. These mines are expected to yield 100,000 tons of ore yearly for some time to come. Other hæmatite mines are at Yanahala, and supplies are also derived from Corea.

Iron Ore in Java.—The United States Consul, B. S. Rairden, states that magnetic iron sand has recently been discovered on the south coast of Java.

Iron Ore in Mexico.—A. Alzate || describes the Tatatila iron ore deposits, Vera Cruz. The ore is a mixture of magnetite and hæmatite containing 63 per cent. of iron, 1·5 per cent. of silica, 2·7 per cent. of sulphur, 0·9 per cent. of manganese, 0·6 per cent. of titanic acid, 1·2 per cent. of magnesia, and 1·2 per cent. of alumina.

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* *Transactions of the American Institute of Mining Engineers*, vol. xxxiv. pp. 841-871.

† *Revue Industrielle de Charleroi ; Stahl und Eisen*, vol. xxiv. p. 857.

‡ *Annales des Mines*, vol. vi. p. 107.

§ *Ibid.*, pp. 106–107.

|| *Annales Mexicanos*, vol. i. p. 14.

Iron Ore in Porto Rico.—The Board of Trade have received a copy of a report * issued by the United States Department of Commerce and Labour, on the mineral industries of Porto Rico for the year ending December 31, 1902, compiled by the Treasurer of the Island, showing that some of the iron ore deposits are of an exceptionally rich character, fully equal in percentage of mineral to the famous Daiquiri mines near Santiago de Cuba. These deposits are situated inland, some 5 or 6 miles from the eastern sea-coast town of Naguabo, and cannot be worked with profit until means of transportation are furnished.

Iron Ore in New Caledonia.—E. Glasser † continues his discussion of the iron ore deposits. He considers the origin of the beds, and their geological and stratigraphical characters. Analyses are given of the large blocks of hæmatite, which are found in great quantities, and contain 68 to 89 per cent. of ferric oxide, 0·6 to 2·0 per cent. of manganese oxide, and up to 5 per cent. of chromium oxide. The silica varies greatly, but other constituents are present only in insignificant amounts. The association of the iron with small percentages of chromium renders these ores, in the author's opinion, of even more value. The massive blocks noted are found in conjunction with thick beds of a granular ore, the particles of which are about the size of peas, and contains over 45 per cent. of metallic iron, or, after calcination, 49·75 per cent., with no injurious impurities. In addition to these two forms, a pulverulent clayey deposit is found containing varying amounts of iron, up to 73·66 of Fe_3O_4, and small amounts of chromium and nickel. He points out that if the associated nickel and chromium passed into the finished metal or steel made from pig irons derived from these ores the economic advantages would at times be considerable, although at others their presence would be prejudicial.

Manganese Ore in Spain.—Particulars have been published ‡ of the manganese mines in the basin of the River Odiel, where there are some three hundred mining concessions. The manganese ores are astonishingly rich, containing as much as 98 per cent. of peroxide.

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* *Mining Journal*, vol. lxxv. p. 616.
† *Annales des Mines*, vol. v. pp. 111–125.
‡ *Revista Minera*, vol. lv. p. 483.

Manganese Ore in Hungary.—C. von John [*] and C. F. Eichleiter give the following analysis of manganese ore from Bösing, Pressburg county, Hungary:—

Mn_2O_3.	Fe_2O_3.	CaO.	MgO.	SiO_2.	P_2O_5.	H_2O.	CO_2.
40·00	21·80	4·64	2·52	13·94	1·34	13·90	1·86

The ore contains 25·26 per cent. of manganese, 15·26 per cent. of ron, and 0·58 per cent. of phosphorus.

Manganese Ore in Queensland.—Some manganese ore deposits in the Gingin, Degilbo, and Warwick districts of Queensland are described by L. C. Ball. [†]

Manganese Ore in India.—Detailed analyses of four Indian manganese ores have been published. Two are from the Nagpur district, one from the Dhar Forest, and one from the Central Provinces. [‡]

Manganese Ore in Georgia.—C. W. Hayes [§] discusses the manganese ores which are closely associated with the iron ores in Georgia, and objects to the theory of their origin proposed by Penrose. T. L. Watson [||] also deals with this subject, and accepts a modified form of that theory.

Chrome Iron Ore.—An analysis of chrome iron ore from the Jelica-Planina near Cacak in Servia yielded, according to C. von John, [¶] the following results:—

Cr_2O_3.	FeO.	Al_2O_3.	CaO.	MgO.	SiO_2.
52·46	15·26	14·01	0·98	7·62	10·15

The deposits of chromite near Daghardi, [**] in the vilayet of Broussa, contain the best quality of chrome ore at present known, and the chief supplies are still drawn from this region, notwithstanding the increasing competition of the chrome ores from New Caledonia, Hungary, and Greece. These ores contain 40 to 60 per cent. of oxide of chrome, but where the percentage falls below 40 per cent. they

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[*] *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. p. 502.

[†] *Geological Survey Report of the Queensland Department of Mines*, No. 189.

[‡] *Records of the Geological Survey of India*, vol. xxxi. pp. 47–49.

[§] *United States Geological Survey*, *Bulletin* No. 213, p. 232.

[||] *Transactions of the American Institute of Mining Engineers*, vol. xxxiv. pp. 643-666.

[¶] *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. p. 502.

[**] *La Tunisie minière*, vol. iv. pp. 3–4.

are not considered to be worth exploiting on account of the great difficulties of transport.

E. Glasser[*] describes the chromite beds found in New Caledonia. They consist chiefly of Cr_2O_3FeO, and contain 50 to 55 per cent. of chromium sesquioxide, while, after washing and preparing, they may run up to 65·8 per cent. He gives statistics of the amounts of ores exported, and detailed descriptions as to their geographical locality, the geology of the beds, and the chemical composition of the mineral, and discusses the cost of extraction and the selling prices realised.

Wolfram.—The occurrences of wolfram and molybdenite, and the mining operations for these minerals, in Queensland, are described by W. E. Cameron.[†]

At Wolfram Camp the gangue is a clean, white quartz, often clear and glassy, occupying the joints and contraction fractures of a grey biotite granite. Associated with the wolfram and molybdenite is a considerable quantity of metallic bismuth, which is also saved and sold. The wolfram and molybdenite occur in large masses scattered through the quartz gangue, the greater portion being easily separated by hand dressing. Details of the characters of the deposits are given.

J. Plummer[‡] describes the occurrence of wolfram in New South Wales.

Nickel Ore.—According to A. P. Colman[§] in the Sudbury nickel deposits, the ores occur in an elliptical band of intrusive rock surrounded by gneisses, greenstones, and metamorphosed sediments, and enclosing a mass about 35 miles long and 8 miles wide of Cambrian tuffs, slates, and sandstones. Along its inner margin the eruptive band is a granite. This becomes more basic outward and passes near the outer edge of the eruptive girdle into norite or gabbro. The ores are limited to the norite, and are found near its outer margin or in dyke offshoots. They occur as irregular bodies of pyrrhotite and chalcopyrite, without well-defined boundaries, and are of plutonic or magmatic origin. There has been, however, some secondary deposition by aqueous solutions in fissures formed since the solidification of the norite. Prior to 1903, the Sudbury mines produced 32,150 tons of nickel and 31,746 tons of copper. Although discovered in 1856, the nickeliferous ores were not worked until 1886.

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[*] *Annales des Mines*, vol. v. pp. 69–110.

[†] *Geological Survey Report of the Queensland Department of Mines*, No. 188.

[‡] *Mining Journal*, vol. lxxvi. p. 404.

[§] *Twelfth Report of the Bureau of Mines*, Ontario, pp. 235–303.

G. Leckie[*] describes the deposits in the islands of Ostero and Foeoe. The mining district of Ringerike and the mines of Askim are also described.

Recent Researches on Meteorites.—The geographical distribution of meteorites is studied by O. C. Farrington,[†] who gives a map showing the localities of all known meteorite falls and finds.

H. A. Ward[‡] has published a catalogue of the Ward-Coonley collection of meteorites. The number of known falls is estimated at 680, and of these 578 are represented in the collection, which includes 258 specimens of meteoric iron and 345 of stony meteorites.

C. Klein[§] gives a detailed list of the 466 meteorites represented in the collection of Berlin University on January 21, 1904. The following are notes on those recently acquired:—

The meteorite from Schafstädt, Merseburg, consists of leucite, anorthite, augite, glassy ground-mass, and ore, having the same composition as a leucite-tephrite. Leucite which is present is icositetrahedra with twin lamellae, has not before been recognised as a meteoric mineral, and the name leuciteuranolith is given to this type of meteorite.

The meteorite from Pavlovka, Balachev, Russia, contains augite, bronzite, enstatite, olivine, anorthite, and perhaps leucite. Analysis, by Lindner, gave the results under I.

A chrondritic stone from Linum, Brandenburg, with olivine, bronzite, augite, metallic iron, labradorite, and troilite gave on analysis the results under II.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	CaO.	MgO.	Na_2O.	K_2O.	MnO.	Metallic Iron.
I.	50·91	6·30	12·74	5·95	6·24	14·69	2·04	0·43	0·30	...
II.	43·05	2·44	...	1·32	3·49	25·72	1·39	0·26	0·20	15·83

	Combined with S.	Ni.	Cu.	S.	P.	TiO_2.	Cr_2O_3.	H_2O.	Total.	Specific gravity.
I.	...	0·10	0·12	...	...	0·03	...	0·44	100·29	3·335
II.	3·23	0·71	...	1·85	0·07	...	0·31	0·12	99·99	3·542

The meteorite from Ternera, Atacama, Chili, contained—

	Fe.	Ni.	Co.	S.	P.	Total.	Specific gravity.
III.	82·17	16·22	1·42	0·13	0·11	100·05	7·694

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[*] *Iron and Coal Trades Review*, vol. lxix. p. 1269.

[†] *Popular Science Monthly*, 1904, pp. 351–354.

[‡] *Catalogue of the Ward-Coonley Collection of Meteorites*, Chicago, 1904, 113 pages; *Geologisches Centralblatt*, vol. v. p. 292.

[§] *Sitzungsbericht der k. preuss. Akademie d. Wiss.*, vol. iv. pp. 114–153. Berlin, 1904.

F. W. Clarke* gives sixty-two analyses of meteorites and of separations from them. The following meteoric irons were analysed: Mount Joy; Pulaski county, Virginia; Ellenboro, North Carolina; Linnville, North Carolina; Cherokee county, Georgia; Chattooga county, Georgia; Hamilton county, Texas; Mart, Texas; Scottsville, Kentucky; Cabin Creek, Arkansas; Grand Rapids, Michigan; and El Capitan, New Mexico.

E. W. Cohen † describes the meteoric irons of Neuntmannsdorf and of Persimmon Creek. Incidentally he notes that cohenite and schreibersite may be distinguished on cut surfaces by covering the crystals with copper ammonium chloride solution. Schreibersite remains unaltered, while cohenite becomes covered with a skin of copper.

Another description has been published ‡ of the meteorite found at Persimmon Creek, North Carolina, in the spring of 1893. The weight of the main mass of this meteorite was 9 lb. 6 oz., but a fragment weighing 11 lb. 13 oz. had been previously detached. The date of the fall is unknown, but the general appearance when found indicated that it had lain in the soil for a considerable period, whilst the inspection of a polished surface afforded evidence of its meteoric origin, and showed that it was composed of a more or less continuous matrix of iron containing troilite, schreibersite, and carbon.

At the meeting of the Asiatic Society of Bengal at Calcutta on December 2, 1903, T. H. Holland § exhibited a meteorite which fell with the meteor seen in eastern Bengal on October 22, 1903. The stone weighs 622 grammes, and is covered with a thin black crust formed by the fusion of the rock during its rapid flight through the air. Several stones are known to have fallen with this meteor, and the complete investment of the fused crust of the one exhibited shows that fusion of the surface occurred after the break-up of the meteorite. Besides the complete proof that the meteor resulted in an actual fall of stones, special interest attaches to this occurrence on account of the observations made from so many points of view permitting the actual path and speed of the object to be calculated.

According to E. W. Cohen, || the meteorite which fell at Ranchito;

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* *United States Geological Survey, Bulletin* No. 228, Washington, 1904, pp. 277–291.

† *Mittheilungen des Nat. Ver. für Neu-Vorpommern und Rügen*, vol. xxxv. pp. 57–60.

‡ *Proceedings of the United States National Museum*, vol. xxvii. No. 1380.

§ *Nature*, vol. lxix. p. 205.

|| *Mittheilungen des Nat. Vereins für Neu-Vorpommern und Rügen*, vol. xxxv. pp. 3–13.

near Bacubirito, Sinaloa, Mexico, consisted mainly of fine grained plessite; the structure is octahedral, with very fine lamellæ. Analysis gave the results under IV. The meteorite from Casas Grandes, El Paso del Norte, Chihuahua, Mexico, is an octahedrite, with lamellae of medium width, and is rich in tænite. Analysis gave the results under V.

	Fe.	Ni.	Co.	Cu.	Cr.	C.	P.	S.	Cl.	Chromite.	Total.
IV.	89·54	9·40	0·98	0·02	0·02	0·01	0·12	0·02	0·02	0·01	100·14
V.	92·66	7·26	0·94	...	0·03	...	0·18	0·02	...	0·03	101·12

Some additional facts concerning the Bath Furnace meteoric fall of November 15, 1902, are given by A. M. Miller.*

F. Berwerth † describes the meteoric stone, weighing 165 grammes, that fell on October 24, 1899, at Peramicho in German East Africa.

F. Osmond ‡ and G. Cartaud find that meteoric iron consists of homogeneous solid solutions of γ-iron and β-nickel.

II.—*IRON ORE MINING.*

Exploring for Iron Ore.—A pocket magnetometer for exploring for iron ore is described by T. Dahlblom. §

According to Jungner,|| diamond boring is being largely used in the Persberg mining district in exploring for iron ore. In five and a half years fifty-one boreholes, with a total depth of 2450 metres, have been executed. Details of the cost and speed of boring are given.

Deep Boring.—A. Lukaszewski ¶ discusses modern practice in deep boring. The rotary diamond drill is very largely employed. The holes themselves, though often very deep, perhaps 3000 feet, are usually very narrow. The methods adopted for breaking off and removing the core are not very successful, as is shown by the fact that the man in charge usually keeps on drilling until he notices a greater

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* *Science*, vol. xviii. pp. 243–244.

† *Sitzungsbericht der k.k. Akademie d. Wiss. in Wien*, vol. cxii. pp. 739–777.

‡ *Comptes Rendus*, vol. cxxxvii. pp. 1057–1059.

§ *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 143–147.

|| *Wermländska annaler*, 1903, p. 12; *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 412.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 221-223.

resistance. This is generally due to the core having just broken off. The holes are often put down at considerable angles, and are naturally more expensive than vertical holes. Even the latter often pass much out of the vertical. This is bad enough in ordinary mining operations, but far worse with the Poetsch freezing method. The author gives an instance where a part of the ground that was believed to have been frozen remained frost-free owing to the pipes in the holes, instead of surrounding the shaft, having been diverted towards the shaft centre. This greatly adds to the difficulties of the Poetsch system at great depths. The author deals with the determination of the strike and dip of the beds passed through, as ascertained from the cores, and also by the clinometer. Macgeorge's apparatus is described. Its use has, however, disadvantages, one of which is connected with the high temperature met with at great depths, from which cause the gelatine used in the clinometer fails to fix the magnet. Meine has endeavoured to overcome these difficulties in his stratameter, which is also described, together with the Gothan modification.

The percussion drill system is well represented by the new methods adopted for ensuring the percussion by Wolski and Pruszkowski, hydraulic pressure being employed in both cases. These methods are specially useful for deep holes. In the Pruszkowski system the rods themselves do not take part in the blow, and the sides of the holes are consequently unaffected, only the crown and cutting attachments being moved. Excellent results have been obtained in Galicia and Westphalia. Other methods are also described, and instances given to show their efficiency in practice.

Shaft Sinking.—H. F. Ellard* describes the sinking of No. 9 shaft, Ashland mine, Lake Superior. He gives dimensioned drawings of the various appliances, and tables of cost and rate of progress.

W. E. Parnall † describes the sinking of the No. 5 shaft at the Tamarack mine to a depth of 4662 feet. The surface was marsh, which had to be drained. The shaft is rectangular. About five years were taken for the work.

Shaft Equipment.—A. Schimitzek ‡ describes a method of replacing the old timbering of a shaft by armoured cement without interrupting mining operations.

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* *Journal of the Lake Superior Mining Institute*, vol. ix. p. 24.

† Paper read before the Lake Superior Mining Institute; *Iron and Coal Trades Review*, vol. lxviii. pp. 1051-1052.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 451-452.

A description has been published* of the winding plant at the Ely iron ore mines, Minnesota.

It is reported † that the deep adit level at Gyalar, near Vajda-Hunyad, is 103 metres below the deepest level of the iron ore mines, and bears the name of Franz Josef I. At 920 metres from the entrance it struck the wall of the iron ore deposit, and proved that the ore is as rich as in the upper levels. The adit was driven entirely by electric rock drills.

Lode Mining.—F. Mládek ‡ discusses the best methods for mining lodes that dip steeply.

E. M. Holmes § describes a gravity incline at the Antonio mine near Daiquiri, Cuba. The mine is worked in levels 40 feet in height. Trucks holding 6 tons each are used. The full capacity of the incline has not been tested, but it will easily lower 2600 tons in ten hours.

Rock Drills.—R. Goebel ‖ gives details of the results obtained with Siemens and Halske percussion rock drills in the iron ore mines of the Ilsede works at Peine. The cost, including current, reserve parts, wages, oil, interest, &c., is 3s. 8d. per shift.

A new rock drill is described by A. Fauck.¶

The results of trials of rock drills for air consumption are given by W. C. Docharty.**

E. J. Munby †† compares electric and compressed air transmission of power for rock drills.

Illustrations are given ‡‡ of Fern's "challenge" sharpener for rock drills. The end of the drill is upset, and then shaped in a number of reciprocating dies.

Illustrations are given §§ of a device, called a "drillibite," for holding and turning a drill through mechanism operated by the striker, thus dispensing with the workman who ordinarily performs these functions in hand drilling.

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* *Génie Civil*, vol. lxv. pp. 25–26.

† *Banyaszati es Kohaszati Lapok*, vol. xxxvii. p. 628.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 185–187, with four illustrations.

§ *Engineering News*, vol. li. pp. 446–447.

‖ *Glückauf*, vol. xl. pp. 664–667.

¶ *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 351–353.

** *Mining Journal*, vol. lxxv. pp. 658–659.

†† *Stevens Institute Indicator; Colliery Guardian*, vol. lxxxvi. p. 767.

‡‡ *Engineering*, vol. lxxvi. pp. 562–564.

§§ *Iron and Coal Trades Review*, vol. lxviii. p. 534.

F. Seymour * describes and illustrates various forms of hand and machine drills used in the Cleveland iron ore mines.

T. H. Proske † illustrates various forms of cross-section bits and gives some notes on means for tempering them.

E. C. Amos ‡ gives an illustrated description of various forms of percussive and rotary drills. Amongst other points mentioned are automatic feeds, drill mountings and air consumption.

C. Weidmann § discusses the action of the valves in compressed air rock drills.

F. E. Shepard ‖ describes the Box electric rock drill, in which the drill is driven from the crank-shaft of an electric-motor through a pneumatic spring cylinder.

G. Hooghwinkel ¶ deals with electric rock drills and the results obtained with them. The solenoid drills have not proved to be successful, and the percussive types now used are driven by rotary electromotors. Three forms are in use—namely, those of Siemens, Gardner, and Locke. In the latter form, the motor is mounted on the drill, while the others transmit power through a flexible shaft. Illustrations are given.

P. Sorgo ** describes the electric percussion rock drill manufactured by the Austrian Siemens-Schuckert works. The author observes that the first record of the use of these machines in Austria was in 1896, when they were put into operation in driving an adit at Dürnberg which was commenced in the year 1596. This was a 1 horse-power drill, and its use spread rapidly. The author now describes the 1 horse-power machine of the type now manufactured.

Explosives.—The Home Office has ordered that all cartridges made of dynamite, gelignite, blasting gelatine, and other explosives containing nitro-glycerine, must always be thawed in a properly designed warming pan before use during the months of December, January, February, and March, and also at any other times if the cartridges are not in a soft or pasty condition.††

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* *Iron and Coal Trades Review*, vol. lxix. pp. 553, 691, 761.

† *Engineering and Mining Journal*, vol. lxxvii. pp. 724–725, 758.

‡ *Engineering Review*, vol. xi. pp. 20–31.

§ *Glückauf*, vol. xl. pp. 1238–1249.

‖ *Transactions of the American Institute of Mining Engineers*, vol. xxxiv. p. 871-885.

¶ *Iron and Coal Trades Review*, vol. lxviii. pp. 1909–1910.

** *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 317–321, with eight illustrations.

†† *Board of Trade Journal*, vol. xlvi. p. 461.

J. K. Karkeet[*] describes various kinds of high explosives, and gives advice as to their safe and economical handling.

The effects of cold and of freezing on explosives are discussed by H. Schmerber.[†]

Gas in Metal Mine.—H. A. Lee[‡] describes the occurrence of nitrogen in a metalliferous mine. The gas shows 96·08 per cent. of nitrogen, and 3·92 per cent. of oxygen by volume.

Wire Ropeways.—The longest wire ropeway, and incidentally the highest engine plant in the world, is now under construction in the Argentine Republic. It is being erected by a Leipzig engineering firm, and is intended for the conveyance of ore from the Mexicana district in the Cordilleras to the Chilecito railway station on the Argentine Northern Railway. It is to have a total length of some 22 miles. The line starts from a point some 1250 feet higher than the summit of the Jungfrau, the maximum elevation being 15,000 feet, while the railway station to which it leads is over 4300 feet above sea-level. The working conditions are very difficult, and some of the spans are very wide—over 2600 feet. Only mules are available for the transportation of the wire rope, iron columns, and the other construction materials required. The loads have consequently to be small, and everything has to be put together on the spot. It is stated that altogether over 88 miles of wire rope will be used.[§]

G. Dietrich[‖] describes some of the more important wire ropeways used at continental mines.

Wire ropeways are described in detail by Stephan.[¶]

Descriptions of wire ropeways have been published by A. A. Bruch,[**] by G. S. Whyte,[††] by S. Miller,[‡‡] by J. H. Janeway,[§§] by W. Hewitt.[‖‖]

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[*] *Journal of the Lake Superior Mining Institute*, vol. ix. p. 39.

[†] *Génie Civil*, vol. xlv. pp. 11–12.

[‡] *Colorado Scientific Society Proceedings*, vol. vii. pp. 163–188; *Mining Journal*, vol. lxxvi. pp. 186–187.

[§] *Stahl und Eisen*, vol. xxiii. pp. 1295–1296.

[‖] *Glückauf*, vol. xl. pp. 883–890.

[¶] *Dinglers Polytechnisches Journal*, August 6, 1904, pp. 502–506.

[**] *Mines and Minerals*, vol. xxiv. pp. 401–405.

[††] *Ibid.*, p. 409.

[‡‡] *Ibid.*, p. 411.

[§§] *Ibid.*, p. 421.

[‖‖] *Ibid.*, p. 428.

L. Marek[*] describes some recent improvements in the construction of wire ropeways.

E. Siermann[†] gives an account of electric wire ropeways.

Handling Iron Ore.—C. H. Wright[‡] describes some modern methods of handling iron ore from the Minnesota mines to the Pittsburg furnaces, giving a number of illustrations of the Mahoning and Fayal mines and of the docks and dock appliances. Various forms of loading and unloading appliances are included, and details are given of the work done by them.

Some details are given[§] of the *Augustus B. Wolvin*, a steamship built to carry 10,000 tons of ore on the great lakes.

III.—*MECHANICAL PREPARATION.*

Iron Ore Concentration at Siegen.—N. V. Hansell[‖] describes the methods of concentration in use in the Siegen iron ore mines. The roasted spathic iron ore is reduced to 32 millimetres in a Blake crusher and then passes to a series of cylindrical drums, the various products being sorted in jigging machines. At the Storch and Schöneberg mine 100 to 120 tons of iron ore is treated in twelve hours. The finished product contains 60 to 62 per cent. of iron, and the tailings 7 to 8 per cent.

C. Blömeke[¶] describes the ore-dressing machinery shown at the Düsseldorf Exhibition, and gives a detailed account of the plant for treating roasted spathic iron ore at the Storch and Schöneberg mine.

Dressing Mesabi Ores.—According to D. E. Woodbridge,[**] Mesabi ores with 55 per cent. of iron are merchantable without con-

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[*] *Banyaszati es Kohaszati Lapok*, vol. xxxvii. pp. 254–259.

[†] *Chemische Zeitschrift*, vol. iii. p. 570.

[‡] *Engineering News*, vol. li. pp. 433–437, with plate.

[§] *Iron Age*, June 23, 1904, pp. 7–8.

[‖] *Bihang till Jernkontorets Annaler*, 1904, pp. 280–282.

[¶] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 17–60.

[**] *Engineering and Mining Journal*, vol. lxxvii. pp. 960–961.

centration, but a good deal of work has been done in the district with leaner ores by the Canisteo Mining Company and at the Arcturus mine. Both jigs and trommels have been used. Much of the ore treated contains loose sand which is easily separated by screening the ore, not much water being required. The phosphorus in the dressed ore is reduced, as much of it goes with the sand.

F. L. Garrison [*] describes the washing of the Appalachian brown hæmatite ores and gives details of the improved log washers used to separate clay. The troughs are arranged in pairs and the "logs" consist of steel shafts with removable teeth. As there is much loss in the fine ore, jigs were used to separate the sand from the limonite. The type of jig used in the Joplin district for separating blende from quartz was experimented with. On the whole the results were not very satisfactory, and the problem still awaits solution.

J. E. Johnson [†] controverts some of the statements made by the previous author as to the percentage losses, and states that at Longdale the finer stuff is screened and treated in spitzlutte. Cast-iron pipes, set with teeth, are used in the log washers. C. H. Thompson [‡] also deals with the loss.

Magnetic Separators.—H. Ostwald, [§] in the course of an illustrated contribution, describes the Wetherill magnetic separator, and instances a number of places where the machine is actually at work, giving, in each case, details as to the nature of the ores treated, and the yield obtained.

An account of the Wetherill magnetic separator has appeared, [||] and some illustrations of the plant at the Lohmannsfeld mine near Neunkirchen.

C. Q. Payne [¶] deals with the magnetic concentration of zinc ores in Virginia. The iron ore concentrates contain 48 per cent. of iron.

J. N. Judson [**] states that a Rowand magnetic separator has been used to remove garnets and other heavy minerals from the diamonds

[*] *Engineering and Mining Journal*, vol. lxxvii. pp. 962–963.

[†] *Ibid.*, p. 997.

[‡] *Ibid.*, vol. lxxviii. p. 5.

[§] *Revue Universelle des Mines*, vol. vi. pp. 194–205, with eight illustrations.

[||] *Iron and Coal Trades Review*, vol. lxix. pp. 184–185.

[¶] *Engineering and Mining Journal*, vol. lxxvii. pp. 1001–1003.

[**] *Ibid.*, p. 996.

in the material which collects on the grease tables at Kimberley.

A description is given* of the application of electricity to the separation and concentration of minerals.

IV.—*METALLURGICAL PREPARATION.*

Briquetting Ore.—The briquetting of iron ores is dealt with by A. Weiskopf,† whose views are controverted by J. H. L. Vogt,‡ who expresses a high opinion of the Gröndal briquetting process, which has been in operation at Bredsjö for three years, and at Herräng for one year. For the Dunderland ore he considers that the cost should not exceed, per ton of ore, 1s. 6d. for mining, and 2s. 6d. for concentration, a total of 4s. Thus per ton of ore briquettes it should be 8s. for mining and concentration, 2s. 6d. for briquetting, 8½d. for railway transport and loading, and 4s. 6d. for freight to England, giving a total of 15s. 8½d.

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* *Electro-Chemist and Metallurgist*, vol. iii. pp. 738–739.

† *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 183–200.

‡ *Zeitschrift für praktische Geologie*, vol. xii. pp. 362–367.

REFRACTORY MATERIALS.

Fireclays of the United States.—H. Ries* has prepared a monograph on the clays of the United States. The origin of clay, its composition, varieties and uses are discussed, and its geological distribution described. The greater portion of the monograph is devoted to the clay deposits east of the Mississippi River. A clay to be considered refractory should not fuse under 3000° F. (Seger cone 27). The following analyses show the composition of several standard American fireclays:—

	1.	2.	3.	4.	5.	6.
SiO_2 . .	74·25	63·00	52·52	59·92	57·80	61·75
Al_2O_3 . .	17·25	23·57	31·84	27·56	25·54	23·66
FeO . .	...	0·46	...	...	...	1·93
Fe_2O_3 . .	1·19	1·87	0·67	1·03	2·51	...
CaO . .	0·40	0·44	0·50	trace	0·25	0·45
MgO . .	trace	0·89	0·19	trace	0·61	0·35
Alkalies . .	0·52	2·69	0·59	0·67	2·69	2·41
TiO_2 . . .	...	1·10	1·68	...	...	1·78
H_2O . . .	6·30	6·45	11·68	9·70	8·35	7·20

1. Bibbville, Alabama. 2. Mecca, Indiana. 3. Mineral Point, Ohio. 4. Salineville, Ohio. 5. East Palestine, Ohio. 6. New Brighton, Pennsylvania.

On a report on the clay resources of the Ohio Valley in Pennsylvania, L. H. Woolsey † points out that the Lower Kittanning clay, while of excellent refractory quality, cannot be used alone for the most highly refractory products. An admixture of flint clay is necessary. Firebricks were made in this region as early as 1839. Several works have been started of late years, but the firebrick industry has receded before the more profitable building brick industry.

Burning Firebricks.—E. Schmatolla ‡ points out that the tem-

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* *United States Geological Survey. Professional Paper* No. 11: 298 pages.

† *Ibid., Bulletin* No. 225, pp. 463–480.

‡ *Die Brennöfen für Tonwaren, Kalk, Magnesit, Zement u. dgl,* Hanover, 1903, pp. 145, with 140 illustrations; *Oesterreichische Zeitschrift für Berg- und Huttenwesen,* vol. lii. p. 316.

peratures in the kilns used for burning the firebricks required for open-hearth furnaces are far below those to which these bricks will be subsequently exposed. The result is that they wear badly, and it is evident that materials which are to be really fire-resisting should be exposed to as high a temperature in the kiln as they will subsequently have to withstand in practice. Gas firing should be generally used for kilns, and the author even recommends the use of the Siemens regenerator method. In the Mendheim kiln, where gas firing is employed, the air is pre-heated. The author would also pre-heat the gas. A very high temperature would then result even when the fuel used was of poor quality.

The Fusibility of Refractory Materials.—G. T. de Saint-Hardouin * discusses the yield point of bricks and other refractory materials. Difficulty was experienced in finding crucibles to withstand the temperatures at which the experiments were carried out. The method adopted to determine the temperature was by Seger cones, and inspection was effected by means of smoked violet glass. The crucibles were made of three parts of fine magnesia, with one part of portland cement, a mixture which yielded good results. The best results were obtained when the crucibles had been subjected to the full action of the furnace without having been allowed to harden too much at first. Ultimately, crucibles were, however, dispensed with in favour of hollows made in the magnesia bricks of commerce, those of the finest grain being easier to work. The following results were obtained with a fine washed clay in which varying proportions of other materials were added, as shown:—

Nature and Proportion of Substances added to the Clay.

Per Cent.		Fusion Point.
20	Carbonate of lithium	1330°
10	Magnesium carbonate	1380°
20	Manganese dioxide	1400°
20	Calcium carbonate	1450°
20	Iron oxide	1610°
50	Infusorial silica	1700°
20	White glass	1710°
20	Titanium oxide	1730°
20	Zinc oxide	1760°
20	Lead oxide	1770°
...	Unmixed clay	1780°
20	Felspar	1810°
20	Alumina	>1810°
15	Chromic oxide	>1810°

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* *Revue de Métallurgie*, No. 2, 1904, pp. 92-103, with nineteen illustrations.

It is pointed out that some error has probably crept into the result relating to the felspar addition, as the amount added would be equivalent to 3 per cent. of potash, and should lower the fusion point.

Graphite.—Graphite is attracting much interest in the region of Lake George and Southern Lake Champlain, New York, and a description of the deposits is given by J. F. Kemp.* The deposits are found in pegmatite veins, in quartzites, in small veins traversing gneiss, and in crystalline limestones. Crucibles for the manufacture of steel take most of the product.

E. Donath † has published a monograph on graphite, containing a bibliography of the subject. Special attention is devoted to the artificial preparation of graphite.

G. A. Stonier ‡ describes the occurrence, origin, mining, preparation, and packing of graphite in Ceylon and India, and adds statistical details and a number of photographic illustrations.

C. von John § and C. F. Eichleiter give the following analyses of graphite, (1) from Marbach on the Danube, (2) from Rastbach in Lower Austria, (3) from St. Michael near Leoben, and (4) from Brloch in Bohemia :—

	1.	2.	3.	4.
Carbon	49·07	91·05	66·72	11·07
Ash	45·10	6·90	29·40	85·37
Water at 100° C. . . .	1·20	0·60	1·20	1·10
Water above 100° C. . .	4·63	1·45	2·68	2·48

In the course of an account of the various applications of electric furnaces, J. Wright ‖ refers to the manufacture of graphite, and gives an illustration of Acheson's furnaces at Niagara Falls.

Bauxite.—Bauxite may contain some excess of alumina to raise the melting point, but excess makes it brittle. Silica prevents shrinkage. When bauxite is mixed with other fireclay, it should first be burnt and ground.¶

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* *United States Geological Survey, Bulletin* No. 225, pp. 512–514.

† *Der Graphit*, Leipzig, 1904.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 536–545.

§ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 495–496.

‖ *Cassier's Magazine*, vol. xxvi. pp. 24–39.

¶ *Thonindustrie Zeitung*, vol. xxvii. pp. 2132–2134.

F. Laur[*] describes the bauxite deposits of Brignoles, Var, France.

F. W. Clarke[†] gives analyses of two samples of bauxite from Jacksonville, Alabama. The results were as follows:—

	Red.	White.
Alumina	41·00	48·92
Ferric oxide	25·25	2·14
Water at 100°	0·65	0·45
Water by ignition	20·43	23·41
Silica	10·25	21·08
Titanic anhydride	2·53	2·52

W. F. B. Berger[‡] describes the occurrence of bauxite in Arkansas, and gives two illustrations of the open workings.

Magnesite.—T. Peters[§] describes the recovery of carbonic acid in magnesite. On calcining the magnesite at 700° C., the carbonic acid is driven off, and being sold at 4 pfennigs per kilogramme covers the cost of the calcination.

F. G. Stridsberg[||] gives the following analyses of Swedish magnesites from Tarrakaise:—

	MgO.	CaO.	Fe_2O_3.	Al_2O_3.	SiO_2.
Norra Jägaren	90·9	0·2	8·3	0·6	0·4
Jägaren	74·7	1·6	21·8	0·3	1·6
Haren	82·0	5·0	12·8	0·3	0·8
Orren	91·4	0·8	6·1	0·4	1·1
Hjärpen	84·9	1·0	12·0	0·4	1·0

Ural Dolomite.—The following (I.) are the average results of seven analyses of local limestones, and (II.) of four analyses of dolomites which were made at the laboratory of the ironworks at Kisel in the Ural[¶]:—

	I. Per Cent.	II. Per Cent.
Silica	1·70	0·55
Alumina	2·72	0·37
Ferric oxide	0·15	
Manganous oxide	traces	traces
Calcium carbonate	92·45	58·88
Magnesium carbonate	0·94	41·35
Bituminous substance	0·14	...
Moisture	0·27	...

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[*] *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 371–386.

[†] *United States Geological Survey, Bulletin* No. 220, p. 21.

[‡] *Engineering and Mining Journal*, vol. lxxvii. pp. 606–607.

[§] *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. p. 904.

[||] *Jernkontorets Annaler*, vol. lviii. pp. 527–528.

[¶] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. li. p. 737.

Carborundum.—T. J. Tone[*] describes the use of carborundum as a refractory lining for furnaces. Silicate of soda is commonly employed as a binding agent.

Siloxicon.—Siloxicon is a compound of oxygen, carbon, and silicon, which is exceedingly refractory, neutral towards acid and basic slags, infusible and insoluble in molten metals. At fusion temperatures it is decomposed by alkalies, and it oxidises at about 1500° C., but will stand 3000° C. in a neutral or reducing atmosphere. It is to some extent self-binding at high temperatures, but usually some agglutinant must be used, such as 2 per cent. of alumina, 5 per cent. of clay, sodium silicate, or tar.[†]

Siloxicon[‡] was discovered by E. G. Acheson, who noted its occurrence in carborundum furnaces which had been inadequately heated. It has a greyish green colour due to ferrous oxide, but if pure it would be probably colourless. Its density is 2·45. Its degree of hardness is not very great. It is extremely fire-resisting, and is neither attacked by acid nor basic slags, nor by fluid metals or furnace gases. The only acid that attacks it is hydrofluoric acid, and this does so only very slowly. In an atmosphere containing oxygen it decomposes at a temperature of 1470° into silicon, carbon and oxygen, but this decomposition is a surface one, only a green skin forming over the material. Before use the siloxicon is powdered, moistened with water, and pressed into briquettes. It is made in electrical furnaces resembling those used for carborundum manufacture, broad electrodes with large areas of surface being employed. They consist of graphite or retort carbon. The furnace is charged with a mixture of fine sand, crushed coke and shavings, the use of the latter being for the purpose of keeping the material porous and pervious to carbon monoxide. The siloxicon has a composition which lies between the limits Si_2C_2O and Si_7C_7O. The furnace temperature must be kept below 2800° C., or else the siloxicon decomposes into silicon, carborundum, and carbon monoxide.

F. A. J. Fitzgerald[§] discusses the refractory materials for electric resistance furnaces. He gives instructions on the preparation of the furnace lining, and describes a series of experiments on the properties of silico-carbides and carborundum.

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[*] *Iron Trade Review*, July 21, 1904, p. 60.

[†] *Ibid.*, May 12, 1904, p. 45.

[‡] *Zeitschrift für angewandte Chemie*, April 29, 1904.

[§] *Electro-chemical Industry*, vol. ii. pp. 439–443.

FUEL.

CONTENTS.

I.—*CALORIFIC VALUE.*

Calorimetry.—T. Gray * and J. G. Robertson have compared the Lewis-Thompson, William Thomson, and bomb calorimeters. The methods of working with these instruments and the calculations for the cooling effect are discussed in detail, and the tabulated results are given of the various instruments working on different coals.

Graefe † gives the results of experiments with various types of calorimeter.

The determination of the calorific value of blast-furnace gases by means of the calorimetric bomb is, according to G. Arth, ‡ unnecessarily tedious. The value may be easily, and at least quite as accurately, calculated from the results of an ordinary analysis.

E. E. Somermeier § has made an investigation of the forms in which sulphur occurs in coal, their calorific value, and influence on the calorific power computed from the Dulong formula. For every 1 per cent. of pyrites sulphur, the calorific power calculated by that formula is 9·6 calories too high.

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* *Journal of the Society of Chemical Industry*, vol. xxiii. pp. 704–707.

† *Braunkohle*, 1904, pp. 121–123.

‡ *Bulletin de la Société Chimique*, vol. xxxi. p. 576.

§ *Journal of the American Chemical Society*, vol. xxvi. pp. 555–568.

Pyrometry.—M. E. J. Gheury * gives the following classification of pyrometric methods :—

I. Dilatation :—

A.—Liquids.

Pressure mercury thermometer.
Baly and Chorley : K. + Na. Up to 700° Centigrade.
Dufour : St. Above 1000° Centigrade.

B.—Solids.

Wedgwood's clay pyrometer.
Brongniart's iron-bar pyroscope.

C.—Gases.

Wiborgh's dial air pyrometer.
Princep : air, gold reservoir. 1829.
Pouillet : air, platinum reservoir. 1836.
Deville and Troost : air, varnished porcelain reservoir. 1863.
Holborn and Day : nitrogen, platinum-iridium reservoir. 1899.

II. Viscosity of gases. Barus, 1899.
III. Density of gases. Töpler, 1895.
IV. Spectroscopic or interferential method. D. Berthelot, 1898.
V. Polarisation and double refraction. Joubert and Le Chatelier.
VI. Radiation, photometric and absorption methods.
VII. Acoustic method. Despertz.
VIII. Specific heat. Pouillet, Violle, Siemens.
IX. Fixed points method.
X. Electrical resistance. Siemens, Callender, and Griffiths.
XI. Thermo-electricity. Le Chatelier.

A description of various forms of pyrometers is then given.

L. H. Schütz † discusses recent progress in the measurement of high temperatures, giving descriptions of the optical pyrometers of Mesuré and Nouel, of Holborn and Kurlbaum and of Wanner.

The annual report of the work done at the Physikalisch-Technische Reichsanstalt contains much information as to the testing of thermocouples, of which 768 couples were tested. Of 34 old couples, which had been in use for years, 26 were found to be correct within 5° C., and only two deviated as much as 17° C. at 1100° C.‡

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* Paper read before the Arc Works Engineering Society; *Engineering*, vol. lxxvii. pp. 655, 699.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 155–161.

‡ *Engineering*, vol. lxxviii. p. 176.

The standardisation of pyrometers is the subject of a bulletin issued by the National Bureau of Standards, Washington. The availability of different forms is discussed, and the elements for standardisation tests are given.

L. Holborn[*] and F. Kurlbaum describe an optical pyrometer, first constructed in 1901, in which the temperature of an incandescent body is determined by photometric observations of the emitted radiations.

S. H. Stupakoff[†] deals generally with high temperature measurements.

Energy available in Fuel.—H. Le Chatelier[‡] discusses, with formulae founded upon the data adduced, the actual quantity of energy available in fuels. It is pointed out that, to arrive at a sound conclusion respecting this question, the method employed should be capable of being reversed, the reactions involved in ordinary combustion being, in their very nature, irreversible.

Fuel economy from the chemical point of view is discussed by J. B. C. Kershaw.[§] He shows that there is considerable scope for economy, and that more attention to the chemical side of the question on the part of engineers would materially reduce their annual expenditure upon fuel.

II.—*COAL.*

Origin of Coal.—H. Hall[||] describes a deposition of coal upon a piece of timber which formed part of a wooden trough into which mine drainage had been pumped for three years. The deposit in no way differed from ordinary coal.

The bitumen of brown coal has been investigated by W. Scheithauer.[¶]

Calcareous Coal in Lanarkshire.—R. W. Dron[**] describes the occurrence of calcareous coal in the Lanarkshire coalfield. This so-

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[*] *Annalen der Physik*, vol. x. pp. 225–241.

[†] *Iron Trade Review*, July 14, 1904, p. 37; August 4, 1904, p. 92.

[‡] *Revue de Métallurgie*, 1904, pp. 402–404.

[§] *Transactions of the Liverpool Engineering Society*, vol. xxv. pp. 27–57.

[||] *Nature*, vol. lxix. p. 250.

[¶] *Braunkohle*, vol. iii. pp. 97–104.

[**] *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 92–96.

called kingle coal contains 32 per cent. of calcium carbonate and 15·5 per cent. of magnesium carbonate, with 32·7 per cent. of combustible matter.

British Coals.—Further analyses of British coals have been collected and compared.*

Burnt Coal.—D. Jackson † gives a note on the natural coke or burnt coal in Douglas colliery, Lanarkshire

Coal in Austria.—C. von John ‡ and C. F. Eichleiter give the results of a large number of analyses of Austrian, Hungarian, and Bosnian coals.

The geology of the coal deposits of Bohemia is described by K. A. Weithofer. §

The stratigraphy of the cannel coal seam at Nyran, in Bohemia, is described by F. Ryba. ||

The Horensko-Koschtialower coalfield, near Semil, in North-East Bohemia, is described by F. Katzer. ¶

The occurrence of brown coal at Hart, near Gloggnitz, in Lower Austria, is described by H. Höfer. **

The Karwin coalfield is described by C. Gaebler.†† This very important coalfield, which lies on the banks of the Oder, in the neighbourhood of Petrzkowitz, contains a large number of workable beds, amongst which are deposits of clay iron stone. The author discusses the probable geological age of the principal beds forming the coalfield, and favours the view that they mainly belong to the lower carboniferous or culm beds, which, absent in Great Britain, form the transition strata between the Devonian and Carboniferous systems.

K. A. Redlich ‡‡ discusses the geological age of the coal-seams found near Radeldorf and Stranitzen in Lower Silesia.

A. Iwan §§ describes the deposits of brown coal in the neighbourhood of the Divača railway station in Carniola, and near Skoflje

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* *Colliery Guardian*, vol. lxxxviii. pp. 684, 730, 812.

† *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 251–252.

‡ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 481–494.

§ *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 355–370.

|| *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 351–372.

¶ *Verhandlungen der k.k. geologischen Reichsanstalt*, 1904, pp. 150–159.

** *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 93–102.

†† *Glückauf*, vol. xl. pp. 1265–1276.

‡‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 403–404.

§§ *Ibid.*, pp. 197–199.

in Istria. The beds are found just below Eocene strata, into which they gradually pass, and in places are of great thickness. The fossiliferous remains met with are described by the author. At the commencement of the nineteenth century some French companies started mining operations in this district, but in a very primitive way, with the result that no actual brown coal-mining ever resulted, and the workings were abandoned. The seams outcrop in very many places. The Britof-Urem-Skoflje seam must be considered as one of the oldest of the brown coals from geological evidence. It varies greatly, however, from brown coals in many respects, more closely approaching a true coal in character. It is quite black, burns with a long flame, and has little moisture. It shows considerable caking qualities, and yields 75·6 per cent. of a hard coke. Mahler and Berthelot found that the brown coal from Britof, in its air-dried state, contained 4 per cent. of water and 5·5 per cent. of a light yellow ash, but as much as 8·8 per cent. of sulphur. It yielded 7951 calories. It can be allowed to remain for a long time exposed to atmospheric conditions without danger. No recent analyses are given. One of the seams mentioned reaches in parts a thickness of 10 feet; and the author anticipates that an annual output of from 60,000 to 80,000 tons would be quite practicable.

Coal in Belgium.—Much information, including a bibliography, is given* regarding the new coalfield in the north of Belgium

B. Schulz-Briesen† gives further particulars of the new coalfield of the Campine in Belgium.

E. Harzé‡ discusses, from a mathematical point of view, the dip of the strata in the new coalfield of the north of Belgium.

P. Habets§ continues a second instalment of an article on the coalfields of Northern Belgium.

Coal in France.—Coal has been struck in French Lorraine‖ at a depth of 700 metres. The coal contains 1·88 per cent. of moisture, 36·12 per cent. of volatile matter, 13·25 per cent. of ash, and 48·75 per cent. of fixed carbon.

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* *Annales des Mines de Belgique*, vol. ix. pp. 657–691.

† *Glückauf*, vol. xl. pp. 722–724.

‡ *Bulletin de la Société Belge de Géologie*, vol. xvii. pp. 568–576.

§ *Revue Universelle des Mines*, vol. vii. pp. 236–251.

‖ *Moniteur des Intérêts Matériels*, vol. liv. p. 2793.

Coal in Germany.—T. Vogelstein * discusses recent discoveries of coal in Rhenish Westphalia. Throughout the whole of the Rhine Valley from Duisburg to Wesel there are collieries, and since the middle of 1902 no less than thirty-four shafts have been sunk. In the Ruhr district workings tend to become deeper, as the use of bituminous coal increases. The chief deposits are between Recklinghausen and Hamm. In and around Bochum many thick seams are worked at depths of about 3000 feet. The use of electricity in mining operations is largely increasing.

Müller † describes the new coal discoveries in the western portion of the Rhenish Westphalian coalfield.

Krusch ‡ gives an account of the new coal discoveries in the eastern portion of the Ruhr coalfield.

Mentzel § discusses the occurrence of dolomite in coal-seams.

At the meeting of the German Geological Society, P. G. Krause || described the deep borehole at Heilsberg in East Prussia. At a depth of 600 metres the Kimmeridge clay was encountered.

F. Heinicke ¶ describes the brown coal deposit at Muskau in Oberlausitz.

J. Herbing ** describes an extension of the coal-bearing area at Landeshut in Silesia.

Coal in Hungary.—A description of the coal-seams worked at the Anina colliery at Fünfkirchen in Hungary has been published.††

Coal in Russia.—The coal needed for the engines and workshops of the great Siberian Railway in 1902 amounted to 278,460 metric tons, while for 1903 the estimated quantity was 327,600 tons. This refers to the Siberian part of the railway, properly so called, from the eastern slopes of the Ural, near Tsheljabinsk, to the town of Irkutsk on Lake Baikal, a distance of about 2020 miles.‡‡ Most of the engines still use wood as fuel. In 1900 there were 507 wood-fired engines to 242 that used coal.

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 226–228.

† *Glückauf*, vol. xl. pp. 800–803.

‡ *Ibid.*, pp. 793–800. § *Ibid.*, pp. 1164–1171 || *Ibid.*, p. 633.

¶ *Braunkohle*, vol. iii. pp. 137–140, 153–159, 197–204, 213–219, with map and eleven illustrations.

** *Centralblatt für Mineralogie*, 1904, pp. 403–405.

†† *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 257–260.

‡‡ *Torgovo Promyhslenaja Gaseta ; Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 266–267.

On the section of this railway above referred to, there are three coal deposits available as a source of fuel. These are as follows :—

(1) The Sudschenka field in the Tomsk district, immediately adjoining the railway and near the river Ob. This coal is low in sulphur, contains from 7 to 11 per cent. of ash, and has the evaporative factor of 6·5. The seams are, however, difficult to mine. They occur at some depth ; there is quicksand to be dealt with, and much water, while the seams themselves are considerably faulted. In 1901 the output of coal from this field was 53,235 tons, and in 1902 about 65,520 tons.

(2) The Ekibas-tus field, about 80 miles to the south of the town of Pavlodar, on the left bank of the Irtish. This field is connected with the harbour at Irtish by a branch line of railway. From this point the coal is conveyed by water to the town of Omsk. It is, however, too high in ash, and of a low evaporative power, and of late has not been used on the Siberian line.

(3) The Tscheremchovo field, not far from the railway, in the Irkutsk district. The coal of this field is not so good as that of the field first described. The evaporative power is from 4 to 5 only ; it loses up to 15 per cent. of its weight when exposed to the air, falls into powder readily, and contains up to 20 per cent. of ash. The seam is some 7 feet thick, about 80 feet only below surface, there is but little water, and shafts can easily be sunk. The output of coal is steadily increasing, and in 1902 amounted to 81,900 metric tons. It is largely used on the railway.

It has been proposed to construct branch lines of railway to connect with the Kusnetzki coalfield in West Siberia, and on Lake Baikal numerous deposits of coal are known, the coal of which is said to be of use for locomotive purposes.

On the line of railway east of Lake Baikal, known as the Transbaikal Railway, as well as on the Chinese East Railway and the South Manchurian branch line, wood is almost the only fuel now employed, though numerous deposits of coal are known to exist. Near Mukden there are collieries from which the coal was sent that supplied Port Arthur and Dalny. Other coal deposits near Possiet Bay and elsewhere that were available for the service of the railway from Vladivostock to Chabarovsk are also mentioned. These raised in 1902 27,846 metric tons. The coal of the island of Saghalien is stated to yield 60 per cent. of coke, to be low in ash, and well adapted for warship purposes. That of the Ussuri province, above referred to, is of poorer quality.

Coal in Spain.—P. Découx* describes the anthracite deposits of the north of Spain. The coal belt extends from Cervera del Rio de Pisuerga to Guardo in Palencia. The anthracite contains 4·5 per cent. of moisture, 3·65 per cent. of volatile matter, 4·4 per cent. of ash, and 87·45 per cent. of fixed carbon.

Coal in India.—R. R. Simpson † reports on the coal deposits of Isa Khel, Mianwali, Punjab. Four divisions are made, and particulars are given of them in detail with a number of assays. At the outcrops, the seams ranged from a few inches up to 5½ feet. At present the workings are very irregular. Labour and water are deficient.

P. N. Bose ‡ reports on the Um-Rileng coal-beds in Assam. Two seams 4 to 6½ feet in thickness were found in one boring.

A series of assays of coal from various localities in India is given.§

Sarat C. Rudra,‖ in a general account of the mineral source of India, gives a brief review of the localities in which coal and peat are found.

Coal in British Columbia.—John Matthews¶ gives an account of the recent exposure of anthracite in No. 2 slope at Cumberland. The seam, which is 4 feet in thickness, and gives on analysis 82 per cent. of fixed carbon, was encountered at a vertical depth of 80 feet, the stopes having been driven a distance of 650 feet. This coal has been formed in a most peculiar manner, and is found under unusual conditions. It is the seam from which the Comox steam coal is mined; in fact, the anthracite and the bituminous coal merge, the former having become metamorphosed by heat. This heating has been effected by an overflow of andesite, ejected from the adjacent mountain range during a period of volcanic action, and covering about 1000 acres of coal-measures to an average depth of 200 feet. Between the coal and the overflow, which appears to have preserved the lower layer from the great heat then prevailing, there are approximately 100 feet of coal-measures, sandstone, and shale. The ground lies at an easy angle, and shows little indication of

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* *Echo des Mines*, vol. xxxi. p. 1116.

† *Records of the Geological Survey of India*, vol. xxxi. pp. 9–34.

‡ *Ibid.*, pp. 35–37.

§ *Ibid.*, pp. 49–52.

‖ *Transactions of the American Institute of Mining Engineers*, vol. xxxiv. pp. 804–835.

¶ *Mining Journal*, vol. lxxv. p. 605.

the faulting which is characteristic of the district generally, and as the coal usually conforms to the contour of the surface, it can be reasonably assumed that the development of this large area will not be handicapped by geological disadvantages.

A. Vicaire * describes the geology of the coalfields in the Crow's Nest Pass, showing the distribution of the seams. In the valley of the Elk, no less than nine seams of 5 feet in thickness are superimposed, while two seams of 36 feet, and two of 30 feet, also occur, making the total thickness over 170 feet. The coal is of good quality, and cokes well. The author gives an historical sketch of the development of the district, and goes on to describe the workings already in progress.

Coal in New South Wales.—The existence of a payable coal-seam in the vicinity of Black Mountain, near Armidale, has been proved. The prospectors drove about 100 feet into the hill, when they struck a seam about 10 feet in thickness. The quality was not marketable, but was improving as the drive became extended.†

Coal in Western Australia.—D. Clark ‡ gives a brief account of the coalfields of Western Australia. The principal field is at Collie, and covers about 50 square miles. In the last six years over half a million tons have been produced, mainly from one colliery, where there are five seams with an aggregate thickness of 63½ feet. In the Irwin field, several boreholes have been put down and a number of seams of bituminous coal have been found.

Coal in the United States.—Analyses of American coals are given by B. Simmersbach. §

H. Macco ‖ drew attention in previous papers to the fact that accurate statements as to the first costs of coal and coke in the United States were not available. Since then E. V. d'Invilliers has given data bearing on this question in a paper read in February 1904 before the American Institute of Mining Engineers. With this paper the author now deals. Other data have also been given by Simmerbach. Incidentally the author points out that, despite the

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* *Annales des Mines*, vol. v. pp. 304–322.

† *Mining Journal*, vol. lxxvi. p. 375.

‡ *West Australian Mining and Metallurgy*, 1904, pp. 191–197.

§ *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 229–233.

‖ *Stahl und Eisen*, vol. xxiv. pp. 579–580.

poor character of the coke-ovens in use in the United States, the quality of the coke produced is far better than is that of the coke made in Germany, and while in Germany no great reduction in the cost of production of coke is now to be anticipated, it is probable that considerable improvement in this direction will be made in the United States.

Coal in Alaska.—F. C. Schrader* describes the coal deposits observed by him in a reconnaissance in Northern Alaska. Coal varying in age from Tertiary to Carboniferous is widely distributed. It occurs in the Koyukuk drainage on the south side of the mountains, in the plateau on the Anaktuvuk, in the coastal plain on the Colville, and on the north-western coast, in the Cape Lisburne region, at Wainwright Inlet, Cape Beaufort, and several points between Cape Beaufort and Cape Lisburne.

In an account of a geological reconnaissance of part of Alaska, W. C. Mendenhall † states that lignite is found on Coal Creek near Dall River and on Kowak River. Other localities in the Mount Wrangell district are also given.

A. H. Brooks ‡ reviews the investigation of the mineral deposits of Alaska, and gives a bibliography of the United States Geological Survey publications dealing with the country.

Coal in Arkansas.—G. L. Fowler § gives an account of the geology, mining methods, and character and value of the coal of the Pocahontas field.

Coal in Colorado.—A. Lakes || gives an account of the geology of the coalfields of Colorado.

G. H. Girty ¶ describes the carboniferous formations of Colorado, and gives a review of the literature of the subject.

In a description of the extensive plant of the Colorado Fuel and Iron Co. at Primero, R. M. Hosea ** describes the coking coal deposits of the Raton field. The coal-seam on which the Primero workings

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* *United States Geological Survey, Professional Paper* No. 20, 139 pages.

† *Ibid.*, Nos. 10 and 15.

‡ *Transactions of the American Institute of Mining Engineers*, September 1904.

§ *Engineering Magazine*, vol. xxvii. pp. 217–232, 383–396.

|| *Bulletin of the Colorado School of Mines*, vol. ii. pp. 11–23.

¶ *United States Geological Survey, Professional Paper* No. 16, 546 pages.

** *Mines and Minerals*, vol. xxiv. pp. 521–526.

are located varies from 6 to 8 feet thick, and is quite clean and free from impurities, although its ash percentage is rather high. Its analysis is as follows:—

	Per Cent.
Fixed carbon	58·61
Volatile constituents	28·52
Moisture	0·69
Ash	12·18
	100·00
Average specific gravity	1·36

This coal is soft and easily mined, and it produces over 50 per cent. of screenings at the tipple suitable for coking, of which the slack is quite free from slate. This mixture makes a dense silvery coke, thickly glazed with graphitic carbon, containing 30 per cent. cell space, and when washed and crushed coal is used this percentage is somewhat higher.

Coal in Kentucky and Tennessee.—According to G. H. Ashley,* the Cumberland Gap coalfield forms part of the eastern edge of the Appalachian coalfield. It lies between Pirie and Cumberland Mountains and extends from Fork Mountain to the heads of Poor and Clover forks of Cumberland River, having a length of 90 miles and a width of 15 to 20. The boundaries are determined by faults. The quality of the coal, the thickness of the seams, and the geology generally are dealt with.

The Cumberland Gap coalfield is described in another paper by G. H. Ashley.† It is situated mainly in Claiborne county, Tennessee, and in Bell and Harlan counties, Kentucky. Maps, sections, and photographic views of the mines accompany the paper.

Coal in Nebraska.—E. F. Burchard ‡ gives an account of the occurrence and character of the lignites of the Middle and Upper Missouri Valley.

Coal in Pennsylvania.—During the past four years the United States Geological Survey § has been engaged in a geological survey of the bituminous coalfields of Pennsylvania. Reports on five of the quadrangles so far surveyed have appeared, and deal with the geo-

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* *United States Geological Survey, Bulletin* No. 225, pp. 259–275.

† *Mining Magazine*, vol. x. pp. 94–100.

‡ *United States Geological Survey, Bulletin* No. 225, pp. 276–288.

§ *Ibid.*, No. 213, pp. 270–275.

logical structure of the region. Accurate topographic maps have been prepared, and upon them the geological formation and the coal outcrops are laid down. By means of structural contours, based upon hundreds of observations and careful compilation of drill records, the anticlines and synclines are represented in detail. The area so far surveyed covers nearly the whole of the Connellsville cokefield, a portion of the gasfield of the Irwin or Port Royal basin, much of the territory along the Monongahela and Youghiogheny Rivers, considerable portions of Armstrong and Indiana counties, and parts of Butler and Beaver counties.

Coal in Brazil.—A. Gertsch [*] describes the coal deposits in Santa Catherina, Brazil.

Coal in Chili.—A. Herrman [†] compares the coal deposits of New South Wales with those of Chili. The Chilian lignites contain half as much ash as the Australian, but are less satisfactory in all other respects.

A consular report states that great quantities of coal exist in the Tertiary measures in the south of Chili, the coalfield extending from latitude 37 degrees to north of Tomé in a long narrow strip, that is widest in the province of Arauco, where coal is found from the Cordilleras to the Pacific coast. The chief mines are those of Lota, Corinel, Lebu, Laraqueta, Talcahuano, and Cerro Verde. The coal from the two latter mines is used to some extent for manufacturing purposes, but its calorific value is too low for steam raising. The coal from the Lebu mine is also inferior, but that from Lota and Corinel is used by vessels in coastwise traffic. This coal contains 50 per cent. of volatile matter, and the coke is too light and friable for use in the foundry. No reliable statistics of output are available, but the estimated production is now about 900,000 tons.

Coal in Mexico.—It is announced that important deposits of coal of excellent quality have been discovered in San Miguel Ayotla in the state of Guerrero, and that a German company will work them. The production of coal in Mexico is now a little over 1,000,000 tons a year.[‡]

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[*] *Finanz Chronik*, vol. ix. p. 290.

[†] *Boletin de la Sociedad Nacional de Mineria*, vol. iii. pp. 81–93.

[‡] *Modern Mexico*, vol. xvii. No. 5, p. 19.

Coal in Peru.—In a monograph on the mineral resources of the province of Hualgayoc, forming the sixth bulletin issued by the corps of mining engineers of Peru, the coal deposits are described by F. Malaga Santolalla.* The geology is described, and details of the methods of mining are given.

Nicanor G. Ochoa,† in an account of the mineral resources of the province of Huanuco, points out that the district of Higueras is of most importance from a mining point of view. Besides metalliferous deposits there is near Chaulan a mine of anthracitic coal.

F. J. Schafer ‡ describes the proposed railway from Chimbote to Huaraz which follows the course of the river Santa, that cuts through carboniferous deposits, and exposes coal-beds for a distance of 40 miles along its banks. The author considers that the 500,000 tons of coal annually imported from England and Australia to the western coast of South America could all be supplied from the Santa Valley coalfield, lying at a distance of only 63 miles from one of its best ports. The quality of the coal varies from anthracite to bituminous, and the following analyses are given:—

	Anthracite. Per Cent.	Bituminous. Per Cent.
Fixed carbon	86·58	64·80
Volatile matter	3·77	21·00
Ash	3·83	5·20
Moisture	4·96	8·30
Sulphur	0·86	0·70

Coal in China.—R. Logan Jack § gives particulars regarding coal and iron ore mines encountered in a journey from Shanghai to the Irrawadi. A very considerable industry in lignite quarrying was observed at Ho-Show Pu.

W. H. Shockley ‖ gives some notes on the coal and iron fields of south-eastern Shansi, China. His estimate of the thickness of coal is somewhat lower than that of von Richthofen, which is about as fair as can be made. Probably 5,000,000 tons are used in this province annually. Assays show:—

Carbon.	Sulphur.	Ash.	Moisture.
84 to 89	0·35 to 0·58	6·9 to 12·0	2·7 to 3·5.

The general geology and some of the deposits are described.

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* *El Asiento Mineral de Hualgayoc;* Lima: 1904.

† *Recursos Minerales de la Provincia de Huanuco;* Lima: 1904.

‡ *Page's Magazine,* vol. iv. p. 491.

§ "The Back Blocks of China." London: E. Arnold, 1904.

‖ *Transactions of the American Institute of Mining Engineers,* vol. xxxiv. pp. 841–871.

Coal in Japan.—The Japanese coalfields are described by T. Moukovsky.* Analyses are given of the coal from Miike, Katsuno, Meo, Akaike, Shimo-Jamada, Miyai, Onoda, Naiga, and Hokkaido.

The Miike colliery produces 61,500 tons monthly, and affords employment to 1058 men. The lump coal contains 34·13 per cent. of volatile constituents, 58·08 per cent. of coke, 7·44 per cent. of ash, 0·35 per cent. of moisture, and 2·73 per cent. of sulphur.

E. Lozé † gives the following recent analyses of Japanese coal:—

	Sorachi (Hokkaido).	Yubari (Hokkaido).
Fixed carbon	56·60	53·10
Volatile matter	37·94	41·06
Moisture	2·54	1·64
Ash	2·92	4·20
Sulphur	0·26	0·21

He also gives for comparison the following analyses of coal from Manchuria:—

	Mukden.	Vladivostok.
Fixed carbon	74·56	43·18
Volatile matter	9·94	36·04
Moisture	0·82	14·10
Ash	14·68	6·68
Sulphur	0·21	0·07

An article on the coal resources of Japan is published.‡ The output in 1901 amounted to 8,945,939 tons. About 70,500 miners are employed. The following are analyses of Japanese coals:—

	Volatile Matter.	Ash.	Fixed Carbon.	Sulphur.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Kogayama	34·2	3·3	58·2	0·75
Namazuta	35·7	4·75	56·5	0·61
Shinnu	37·1	6·25	53·5	0·48
Nakanoshima . .	37·7	3·35	57·3	0·31
Takashima . . .	35·5	6·35	56·4	0·72
Hyakumansaki . .	39·0	7·95	51·4	0·81

The coal-seams worked by the Hokkaido Colliery Company are described by K. Yonekra. §

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* *Gornosavodsky Listok*, 1904, Nos. 3 to 8; *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 302–304, 320–322.

† *Annales des Mines de Belgique*, vol. ix. p. 616.

‡ *Moniteur des Intérêts Materiels*, vol. liv. p. 2228.

§ *Mines and Minerals*, vol. xxiv. pp. 533–535.

Coal in Turkestan.—W. Dill[*] describes the coal deposits of Turkestan. Cretaceous coal is met with at numerous localities, while coal of carboniferous age has been found near Samarkand and in the Sergiopol region.

Coal in New Caledonia.—The coal deposits of New Caledonia are described by E. Glasser,[†] who gives an account of the geology of the country, a history of the search for coal, and details of the Noumea and Moindou basins.

Coal in the Faröe Islands.—G. A. Greener [‡] states that coal is found on four of the Faröe islands, but the deposits are only extensive on Suderö. Several sections are given, showing seams from 2 to 9 feet in thickness, and varying from lignite to anthracitic. The workings are small. A history of coal in these islands is appended.

Coal on the Zambesi.—According to A. St. H. Gibbons,[§] on the Zambesi, notably in the neighbourhood of the Kerabaas Rapids and the Guay districts, coalfields of great promise have been discovered. It is stated that the coal in the latter country is quite exceptional in quality. It is to be found on the Marotseland side of the river as well as to the south. The western side of Marotseland did not appear to offer promise of mineral wealth.

Peat.—B. Simmersbach [‖] describes the exhibits at the Peat Industry Exhibition held in Berlin in February 1904.

A company has been formed to treat peat at Markaryd by the Ziegler process, by which from 1000 lbs. of air-dried peat there can be extracted 580 lbs. of peat charcoal, 5 lbs. of paraffin, 30 lbs. of gas oil, 4 lbs. of ammonia salts, 6 lbs. of acetate of lime, 2 lbs. of methylic alcohol, 3 lbs. of oil, and 50 lbs. of pitch.[¶]

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[*] *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 60–62, 92–94.

[†] *Annales des Mines*, vol. v. pp. 503–699.

[‡] *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 331–342.

[§] "Africa from South to North through Marotseland." London: John Lane.

[‖] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 232–244.

[¶] *Affarsvärlden.*

III.—*CHARCOAL.*

Charcoal from Bosnia.—C. F. Eichleiter[*] gives the following analysis of charcoal from Busovac in Bosnia:—

Carbon	85·06
Hydrogen	2·39
Oxygen and nitrogen	5·45
Water	4·80
Ash	2·30

The calories computed from the analysis are 7393, and by the Berthier method 6141.

Charcoal Plant at Cleveland.—The charcoal plant of the Pioneer charcoal furnace, Cleveland, Ohio, consists of 86 kilns, each holding 80 cords of wood. Some details of the by-product plant are given.[†]

Gases in Charcoal.—Sir J. Dewar[‡] gives a note on the absorption and thermal evolution of gases occluded in charcoal at low temperatures.

IV.—*COKE.*

Beehive Coke-Ovens.—R. M. Hosea[§] gives sections of the beehive ovens at Segundo, Colorado.

At Smock, near Brownsville, Pennsylvania, there is a plant of 402 beehive ovens. The new ovens are 12½ feet in diameter, and 7½ feet in height.[||]

Coke in British Columbia.—Nearly half the coal produced at Crow's Nest is made into coke,[¶] mostly in ovens of the beehive type. In 1903, 167,739 tons were made. The bulk of the make was disposed of to smelters in districts tapped by the Canadian Pacific Railway and by the Great Northern Railway of Canada.

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[*] *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. p. 513.

[†] *Iron Age*, June 23, 1904, pp. 26–28.

[‡] *Proceedings of the Royal Society*, vol. lxxiv. pp. 122–127.

[§] *Mines and Minerals*, vol. xxv. p. 6.

[||] *Engineering and Mining Journal*, vol. lxxviii. pp. 102–103.

[¶] *Iron and Coal Trades Review*, vol. lxix. pp. 1583–1584.

By-Product Coke-Ovens.—A. Ernst [*] gives particulars of the coal and coke handling plant of the Lackawanna company at Lebanon, Pennsylvania, and describes the coal-stamping machines, of which eight are in use. The plant, as a whole, consisting of 232 Otto-Hoffman ovens, is described by W. B. Rothberg.[†]

A. Czermak [‡] describes the starting of an Otto coke-oven plant with under-firing and by-product recovery for the treatment of a coal, from the Hohenegg pit at Karwin, that caked with difficulty.

Illustrations are given of the coke-ramming machines in use at the Semet-Solvay ovens at the Wigan coal and iron company's works.[§]

A. Pourcel [‖] contributes a note on the manufacture of coke from rich coals, pointing out that this coke yields excellent results, both physically and chemically.

Foundry Coke.—F. Schreiber [¶] observes that about 80 per cent. of all the coke made finds its way into works labelled as blast-furnace or foundry coke. These two kinds differ chiefly in the size of the pieces. Blast-furnace coke serves to yield heat, and, in addition, carbon monoxide, for the reduction of the iron ore in the blast-furnace. Before all other properties it is required to be strong enough to carry a heavy burden without crushing. The purpose to which foundry coke has to be put involves only the evolution of heat—*i.e.* it should be capable, as far as possible, of being burnt to carbon dioxide. The author discusses the physical properties which a coke should possess to justify its description of foundry coke. To enable him to do this he deals with the manufacture of coke and with its structure. Four samples of Westphalian coke showed on assay:—

Sample.	Ash.	Calorific Power.	Pore Space.
	Per Cent.	Calories.	Per Cent.
1	10·65	7121	48·63
2	6·86	7339	53·57
3	9·09	7248	52·21
4	10·15	7012	46·40

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[*] *Mines and Minerals*, vol. xxiv. pp. 359–361.

[†] *Ibid.*, pp. 362–365.

[‡] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 467–469, 485–488.

[§] *Iron and Coal Trades Review*, vol. lxix. p. 410.

[‖] *Revue de Métallurgie*, 1904, pp. 284–286.

[¶] *Stahl und Eisen*, vol. xxiv. pp. 521–527, with eight illustrations.

The cell space consequently averaged about 50 per cent. of the whole mass. There are no better results than can be obtained from Lower Silesian coke made from stamped coal. Indeed, for equal ash contents the Lower Silesian coke give the same amount of heat, and it is at the same time denser than a coke made from good Westphalian coal. In cupolas, when smaller-sized pieces of coke are being burnt, a much larger flame is observable at the throat—*i.e.* too much carbon monoxide is being produced. By melting the iron low down in the cupola the reduction of carbon dioxide by carbon is diminished. This action of the carbon of the coke is much stronger in the case of porous coke to what it is when dense coke is used. When too much coke has to be burnt in a cupola, however, this is often the fault of the cupola rather than of the coke, as the author shows by experimental results. A cupola to give good results should, he concludes, be cylindrical in shape throughout, without being narrowed at any part. It should not be less than 27·6 inches in diameter at the fusion zone, and a better result would be obtained if its diameter were 31·7 inches; the tuyeres should be as large as possible, and arranged slit-fashion all round the cupola.

O. Simmersbach * observes that good foundry coke is made in Belgium from coal containing 4 to 6 per cent. of ash and 20 per cent. of volatile matter. The yield of coke is about 80 per cent. Foundry coke with 6 to 8 per cent. of ash should have a true specific gravity of 1·70 to 1·75, and an apparent one of 0·90. The strength of the coke is often determined by ascertaining the degree of fineness obtained on grinding in a special apparatus for a specified time. For instance, soft coke treated in this manner, and then passed over a sieve, gave only 50 per cent. of residue, while in the case of hard, firm coke similarly treated, only from 10 to 20 per cent. passed through the sieve. The method of determining the combustibility of the coke is also described. This consists in noting the amount consumed in a given period on a special fire grid. The fusibility of the ash of coke depends on its contents of silica, alumina, and the oxides of iron and other metals. Distinguishing the oxygen of the silica divided by that of the alumina as A, and the oxygen of the alumina divided by that of the oxide fluxes as B, then if B divided by A is 4, the melting point of the ash will be about 1500° C.; while if this ratio approaches 1, then the melting point will be about 1300°.

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* *Stahl und Eisen*, vol. xxiv. pp. 795–796; *vide* also *Bulletin de l'Association Belge des Chimistes.*

Belgian coke contains on the average 0·8 per cent. of sulphur. The phosphorus contents varies between 0·02 and 0·03 per cent. Assays showed different kinds of Belgian coke to contain the following percentages of ash and volatile products:—

	Ash.	Volatile Products.
	Per Cent.	Per Cent.
Foundry coke—average of 15	6·80	0·74
,, ,, maximum	9·30	1·40
,, ,, minimum	5·30	0·40
,, ,,	10·30	1·40
,, ,,	4·60	1·50
Blast-furnace coke, unwashed	22·40	1·80
Blast-furnace coke	16·70	2·76

The following are analyses of Belgian, German, and other cokes:—

Coke.	C.	S.	P.	Ash.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Agrappe, unwashed	87·54	0·22	...	11·40
,, washed	93·37	0·18	...	5·53
Chevalières, washed	92·24	0·80	...	6·96
Strepy, unwashed	88·01	0·67	...	11·32
Tilleur	87·50	0·50	...	12·00
Three German cokes	88·43	0·87	...	10·70
St. Etienne collieries	86·60	0·40	...	13·00
Carmaux, washed	93·13	?	trace	6·38
Béthune	91·17	0·30	0·028	8·50
Lambton, washed	94·01	1·05	...	?
Monmouth, washed	89·05	0·96	0·049	8·29

Special importance is attached in Belgium to low moisture contents in foundry coke, one works allowing the coke to cool for twenty-four hours out of contact with air, thus entirely avoiding the use of water.

Utilisation of Coke-oven Gas.—G. Baum * has published a volume of 124 quarto pages with 90 illustrations and 5 folding plates. It is a complete account of the utilisation of coke-oven gases, and deals in great detail with the application of such gases for driving gas-engines. Chapters are devoted to the composition and calorific value of coke-oven gas, and to the cleaning of coke-oven gas, whilst the various types of gas-engine are fully described. The remarkable

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* *Die Verwertung des Koksofengases.* 1904. 4s. (Berlin: J. Springer. London: Williams & Norgate.)

success that has attended the use of blast-furnace waste gases as motive power indicates that the new method of utilising coke-oven gases is likely to prove equally advantageous.

Details are given * of some steam-raising tests with coke-oven gases near Newcastle-on-Tyne.

Coking Coal.—O. Simmersbach † observes that the chemical changes which take place when coal is coked are far from being thoroughly understood. In the first place opinions differ as to the fusibility of bituminous coal. Some hold that coals may show all degrees of fusibility, while others hold that they do not melt at all without decomposition, coking being due to the decomposition of hydrocarbon at high temperature and to the deposition of finely divided carbon which, by cohering, gives the appearance of caking to the whole mass. These theories the author discusses. He holds that the latter theory does not accurately explain the caking process. The connection, at one time supposed to exist, between the caking properties of a coal and the percentage of hydrogen it contains has been disproved, and that the caking properties of a coal is linked to a certain definite carbon percentage is also false, for two coals with the same ultimate chemical composition may behave altogether differently. This the author illustrates by examples. Again, molecular rearrangements may be due to other than chemical causes such as pressure, which has much to do with the properties of a coal. Q. Maiorana has succeeded in converting coke into graphite by heating it under a pressure of 11,000 atmospheres to 2000° C. The author thinks that several different forms of carbon occur in coals, and that under varying conditions they may undergo change in the coal, molecular rearrangement taking place.

Peat-coking.—K. Heine ‡ describes the experiments made by the Prussian Government at Oldenburg on coking-peat. The official report on the experiments has been published by L. C. Wolff. §

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* *Iron and Coal Trades Review*, vol. lxix. p. 628.

† *Stahl und Eisen*, vol. xxiv. pp. 446–452, with four illustrations.

‡ *Chemische Zeitschrift*, vol. iii. pp. 289–291.

§ *Verhandlungen des Vereins zur Beförderung des Gewerbefleisses.* October 1903.

V.—*LIQUID FUEL.*

Origin of Petroleum.—The question of the origin of petroleum has received further attention, and the problem has been attacked on somewhat novel grounds. Some varieties of oil show the power of rotating the plane of polarised light, a power that is considered to be possessed only by bodies of organic origin. L. A. Tshugaieff [*] and P. E. Walden have dealt with this aspect.

E. Coste [†] reiterates his statements as to the volcanic origin of oil, and maintains that any other source is impossible.

Petroleum in Galicia.—The occurrence of petroleum at Boryslaw and its bearing on the geology of the district are described by C. Angermann.[‡] A map and geological sections accompany the paper. The petroleum and ozokerite deposits at Boryslaw are also described by J. Holobek.[§]

R. Züber [||] describes the geological condition of the Boryslaw and of the Opaka-Schodnica-Urycz oilfields.

The deepest well at Boryslaw, Galicia, is 3720 feet in depth. It was sunk in two years, starting at 20 inches in diameter and finishing at 5 inches.[¶] Particulars are also given of other deep wells in this district.

At the end of June there were in Galicia 244 boreholes for petroleum, of which 86 were productive. Of these 4 have attained a depth of 1000 metres and 64 have exceeded 900 metres.[**]

Petroleum in Germany.—Hoyer [††] describes the occurrence of petroleum in Germany and gives detailed particulars of the composition, origin, and history of the Wietze petroleum.

P. Dvorkovitz [‡‡] reviews the oilfields of Germany. They are also dealt with by J. H. Sachse,[§§] who gives analyses of the oil.

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[*] *Petroleum Review*, vol. x. pp. 444–445.

[†] *Journal of the Franklin Institute*, vol. clvii. pp. 443–454.

[‡] *Congrès Géologique International Compte Rendu de la ix. Session.* Vienna, 1904, pp. 767–776.

[§] *Ibid.*, pp. 777–786.

[||] *Zeitschrift für praktische Geologie*, vol. xii. pp. 86–94; *Petroleum Review*, vol. x. pp. 293, 310, 332, 353.

[¶] *Petroleum Review*, vol. xi. pp. 105, 151.

[**] *Moniteur du Pétrole Roumain*, vol. v. p. 601.

[††] *Journal für Gasbeleuchtung*, 1904, pp. 762–768.

[‡‡] *Petroleum Review*, vol. x. p. 223.

[§§] *Ibid.*, pp. 364, 403, 423.

Petroleum in Roumania.—A monograph on the Grozeshti oilfield in the Bacau district has been published by C. R. Mircea.*

An official monograph on the Roumanian oilfield has been compiled under the auspices and with the assistance of the leading authorities on petroleum and petroleum mining in Roumania. It deals exhaustively with the geological relations and characteristics of the Roumanian oilfield, with the composition of the different products obtained, and also provides valuable statistics.

Petroleum in Russia.—F. Thiess † describes the occurrences of petroleum in European and Asiatic Russia.

In a report of the Russian Geological Survey, A. Riabinin ‡ gives an account of the geology of some oilfields in the Sighenakh district, Tiflis. The deposits do not appear to be of commercial importance.

It has been generally considered that the petroleum deposits of the Kuban province of north-western Caucasus had their origin in the Sarmatic and Mediterranean beds of Tertiary age. W. I. Wind § shows that petroleum in Kuban originates also in deeper-lying Tertiary strata consisting of a dark, almost black clay, containing large quantities of remains of fishes as well as of carbonised plants.

The Russian papers report that a rich flow of oil has been discovered at Chatma at a depth of 690 feet. The increasing volume of the gases emanating give reason to anticipate that a spouting-well will result.

Petroleum in Alaska.—G. C. Martin ‖ gives details of the occurrence of petroleum in Alaska.

Petroleum in California.—The occurrence of petroleum in California is described by B. Simmersbach. ¶

Petroleum in Texas.—The recent developments of the oilfields in Texas are described by H. G. Spaulding.** Some photographs by

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* *Moniteur du Pétrole Roumain*, vol. v. pp. 407–409.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 12–16.

‡ *Geologisches Centralblatt*, vol. v. p. 293.

§ *Bulletin of the St. Petersburg Society of Naturalists*, 1904, No. 4.

‖ *United States Geological Survey, Bulletin* No. 225, pp. 365–382; *Petroleum Review*, vol. x. pp. 393–394.

¶ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 245–263.

** *Petroleum Review*, vol. x. pp. 205–206.

H. T. Burls [*] are given of the new Batson field, of which further particulars have appeared. [†]

L. Hager [‡] discusses the connection of the mound-like elevations and salines with the occurrence of oil in the Spindle Top, Sour Lake, and other oilfields of Louisiana and Texas.

Petroleum in Wyoming.—E. E. Slosson [§] gives some analyses of petroleum, from the Bonanza field in Wyoming. They contain a large proportion of the lighter oils.

Petroleum in Mexico.—The discovery is announced of petroleum deposits at San Miguel Amilanco, Durango. [||]

M. Alcala [¶] describes the petroleum deposits of Pichucalco, Chiapas.

It is announced that an American company with a capital of 10,000,000 dollars has been formed to work the petroleum deposits at El Cuguas in the State of Vera Cruz. [**]

A description is given of the resources of the less important petroleum-producing countries, Mexico, the Argentine, Peru, Algeria, Cape Colony, Persia, China, and India. [††]

Petroleum in China.—Some illustrations are given [‡‡] of the native boring plant used in China for oil wells. A Foreign Office report on the petroleum trade of China has also appeared.

Petroleum in Japan.—A detailed history of the Japanese oil industry has been published. [§§]

Petroleum in Persia.—H. L. Rabino, British Consular Agent, reports that in the lower valleys of the Kermanshah province, near the Turkish frontier, there exists a wide oil belt, which extends south from Kerkuk, in Turkey, to Shushter, in Persia, and even to the Island of Hormuz, following a north-west to south-east direction. The principal oilfields of the province of Kermanshah are those of

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[*] *Petroleum Review*, vol. x. p. 207.

[†] *Ibid.*, pp. 156, 282, 285.

[‡] *Engineering and Mining Journal*, vol. lxxviii. pp. 137, 180.

[§] *Petroleum Review*, vol. x. p. 246.

[||] *Annales Mexicanos*, vol. i. p. 184.

[¶] *Revista de la Soc. Cient. Antonio Alzate*, vol. xiii. pp. 311–326.

[**] *Annales Mexicanos*, vol. i. p. 58.

[††] *Moniteur du Pétrole Roumain*, vol. v. pp. 625–627.

[‡‡] *Petroleum Review*, vol. xi. pp. 163–165.

[§§] *Mining Journal*, vol. lxxv. pp. 689, 711.

Chia-surkh, Shah-Murad, Kerim Khan, and Bazargar, Hoorin, Gahwarreh, and Shian. There are also indications of petroleum at other localities. From the numerous ancient cemeteries and fire temples found in these districts it is evident that the extraction of the oil has been carried on since the remotest antiquity, and, to this day, the Kurds get the oil in what must have been the most ancient way of obtaining petroleum. There is usually a well some 24 feet deep in the shape of a funnel, the top being 15 to 30 feet wide, and the bottom 10 feet. At the bottom is a wooden platform giving access to two smaller wells some 30 feet deep. In these wells salt water and petroleum collect. The wells are emptied every five or six days by means of a bucket. The salt water is turned into tanks for evaporation, and the salt is sold in Kasr-i-Shirin.*

Petroleum in the Philippines.—F. H. Oliphant † states that petroleum exists on several islands of the Philippines. The best oil is found in a bed 20 feet in thickness at a depth of 400 feet.

Petroleum in Turkestan.—W. Dill ‡ describes the occurrence of petroleum in Turkestan. The petroleum wells of Fergana may be regarded as the continuation of those in Persia and on the Caspian Sea. The occurrence of petroleum at Schirabad in Buchara and in Afghanistan is also noted.

Petroleum in Africa.—The petroleum discoveries made at Cameroon by a West African company are of considerable importance. § The oil resembles that of Roumania, and yields 35 per cent. of crude petroleum, 50 to 55 per cent. of mineral oils, 5 per cent. of benzine, and 5 per cent. of tar.

Petroleum in New Caledonia.—E. Glasser || contributes a note relative to the discovery of oil at Koumac five years ago. The specific gravity was 0·93. It was not of much use as an illuminant, except in lamps of the Wells type, but was a good lubricating oil. The oil has since been lost sight of.

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* *Mining Journal*, vol. lxxvi. p. 10.
† *Engineering and Mining Journal*, vol. lxxvii. p. 880.
‡ *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 95.
§ *Moniteur du Pétrole Roumain*, vol. v. p. 455.
|| *Annales des Mines*, vol. v. pp. 551–553.

Oil Shale.—J. Plummer* describes the oil shale deposits of Australia and gives a section of the vertical retort used for the distillation at Torbane, New South Wales.

Asphalt.—The origin of natural asphalt or bitumen has given rise to much speculation, and the suggestion has been made that it is produced by the destructive distillation of vegetable remains mixed with organic matter, and especially with fish. Another possible explanation is suggested by the production of an artificial asphalt by heating natural petroleum with sulphur. The series of paraffins is not affected by this treatment, but the naphthenes which are present in the petroleum undergo condensation and give rise to bodies which may be regarded as typical constituents of asphalt. Two of these prepared by the action of sulphur on acenaphthene have recently been described by K. Dziewonski.†

The system of mining bituminous limestone at Limmer, near Hanover, has been described by W. Bergmann.‡ The portions of the deposit mined are replaced by flushing with sand, thus enabling all the material to be extracted.

Boring for Petroleum.—An account is given by A. Fauck § of his deep-boring system. The terminal velocity of 39 inches per second is reached with a fall of less than 2 inches, as compared with a customary terminal velocity of thrice that amount, but with a ten times greater fall. The small fall the author proposes has proved very effective at depths of some 1100 yards. A spiral spring is employed to effect the increased velocity, and a rope is used. This rope method, the author observes, is the one commonly employed in the United States.

Illustrations are given || of the "Express" boring arrangement used by A. Fauck & Co.

Illustrations are given ¶ of a new design of deep-boring apparatus for oil.

A description of the Meine stratameter for surveying boreholes has been published.**

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* *Engineering and Mining Journal*, vol. lxxviii. pp. 66–67.

† *Berichte der deutschen chemischen Gesellschaft*, vol. xxxvi. pp. 3768–3774.

‡ *Glückauf*, vol. xl. pp. 1397–1403.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. *Beilage* No. 5, pp. 34–35.

|| *Petroleum Review*, vol. xi. pp. 83–84.

¶ *Ibid.*, vol. x. pp. 212–213.

** *Boletin Minero*, vol. vii. p. 366.

C. Hoïsescu* discusses the question of water in boreholes for petroleum.

Prevention of Fires at Petroleum Wells.—A. Fauck,† in a paper read before the Austrian Society of Engineers and Architects, states that in order to prevent fires, a thick iron plate is placed above the well in the Baku district. The oil will then strike against this and fall back. Perhaps the Texas method of a strong cone-shaped cap is the simplest arrangement. If the oil is free to escape as a shower, the danger is of course greatest when there is a strong wind blowing. Other points of difficulty in connection with the working of petroleum wells are also dealt with.

Uses of Petroleum.—P. Dvorkovitz ‡ reviews the uses of petroleum for lighting, lubrication, and fuel.

The use of petroleum as fuel is discussed by J. Muck,§ and also by A. M. Bell.‖

Petroleum Derivatives.—The official nomenclature for petroleum derivatives, drawn up by the Russian Government, has been published.¶ The definitions are as follows: (1) *Crude petroleum* is the term to be used when the flashing point does not exceed 70° C.; (2) *petroleum ether* has a specific gravity below 0·7, and distills below 80° C.; (3) *light benzine* has a specific gravity of 0·7 to 0·717, and contains 5 per cent. of substances distilling at 100° C.; and (4) *heavy benzine* has specific gravity of 0·717 to 0·730, distills at 100° C., and has less than 5 per cent. of substances distilling at 100° C. The various illuminating oils, lubricating oils, and combustible oils are similarly defined.

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* *Moniteur du Pétrole Roumain*, vol. v. p. 573.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii.; *Beilage* No. 5, pp. 35–36.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 495–515.

§ *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 335–344.

‖ *Report of the Seventy-third Meeting of the British Association*, p. 780. London: 1904.

¶ *Moniteur du Pétrole Roumain*, vol. v. p. 315.

VI.—*NATURAL GAS.*

Natural Gas in Sussex.—The history of the discovery of natural gas in the Heathfield district, Sussex, is traced by R. Pearson.[*] The first find appears to have been made at Hawkhurst in 1836.

H. B. Woodward[†] gives some notes on the occurrence of natural gas at Heathfield in Sussex, and some sections of the borings. R. Pearson[‡] also deals with this subject, and a bibliography is given by W. Whitaker.[§]

Natural Gas in Austria.—R. J. Schubert[||] gives the results of a microscopic examination of the strata passed through by the deep borehole put down by the Austrian Government at Wels. A bibliography of the Wels borehole is appended.

M. Wielezynski[¶] gives an account of the gases accompanying the petroleum of Galicia.

Natural Gas in Russia.—It is intended[**] to develop the natural gas supply at Surakhany, near Baku, in order to replace oil for heating the stills. Ten boreholes are to be sunk.

Natural Gas in Pennsylvania.—R. W. Stone[††] describes the geological structure of Eastern Greene County, Pennsylvania, and discusses the distribution of gas and oilfields with relation to the structure. Gas is found in commercially important quantities in the Big Injun, Gantz, Fifty-foot, Fifth and Bayard sands. The principal accumulations of gas are either on the crests of the anticlinal folds or on the steep flanks. The oil pools are situated at points on the flank of an anticline, where the dip is considerably flattened or at a low point on the crest of an arch. Wells drilled in the bottoms of the synclinal basin have for the most part been unproductive.

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[*] *Report of the Seventy-third Meeting of the British Association*, pp. 785–787. London: 1904.

[†] *Transactions of the Institution of Mining Engineers*, vol. xxv. pp. 717–723; see also *Journal of the Iron and Steel Institute*, 1903, No. II. p. 580.

[‡] *Ibid.*, vol. xxvi. pp. 494–507.

[§] *Ibid.*, p. 507.

[||] *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 385–422.

[¶] *Moniteur du Pétrole Roumain*, vol. v. p. 586.

[**] *Petroleum Review*, vol. xi. p. 131.

[††] *United States Geological Survey, Bulletin* No. 225, pp. 396–412.

M. L. Fuller[*] describes the Hyner gas pool, Clinton County, Pennsylvania. It is of interest as being one of the newest and most easterly of the gas pools of Pennsylvania.

M. L. Fuller[†] describes the occurrence of natural gas and its relation to geological structure in the Brownsville quadrangle (about 225 square miles) in South-Western Pennsylvania.

According to C. W. Tideström,[‡] analyses of the natural gas used at Pittsburg and at Chicago are as follows:—

	Pittsburg.	Chicago.
	Per Cent.	Per Cent.
CO	0·55	...
H	1·89	...
CH_4	92·84	92·82
C_2H_4	0·20	...
CO_2	0·20	3·00
O	0·35	0·20
N	3·82	3·78
H_2S	0·15	0·20
Totals	99·82	100·00

VII.—*ARTIFICIAL GAS.*

Gas-Producers.—H. Jahns[§] describes the gas-producer plant at the Von der Heydt Colliery, Saarbrücken, where waste containing only 30 per cent. of coal is utilised.

Illustrations are given[||] of Deschamp's down-draught gas-producer.

Tests have been made of a Pierson suction gas-producer, using gas-coke as fuel.[¶]

J. G. Sanderson[**] gives the results of gas-producer plants, utilising anthracite. The following analyses are given:—

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[*] *United States Geological Survey, Bulletin* No. 225, pp. 392–395.

[†] *United States Geological Survey. Atlas Folio,* No. 94.

[‡] *Bihang till Jernkontorets Annaler,* 1903, pp. 351–368, 389–401.

[§] *Zeitschrift des Vereines deutscher Ingenieure,* vol. lviii. pp. 311–315.

[||] *Iron and Coal Trades Review,* vol. lxviii. pp. 1534–1535.

[¶] *Engineering,* vol. lxviii. p. 285.

[**] Paper read before the Scranton Engineers' Club; *Engineering and Mining Journal,* vol. lxxvii. p. 563.

	Welsh Anthracite.	Pennsylvania Anthracite.	
	Dowson Producer.	Taylor Producer.	Sanderson Producer.
	Per Cent.	Per Cent.	Per Cent.
H	18·73	4·51	19·35
CH_4	0·62	1·79	0·66
CO	25·07	25·38	28·80
CO_2	6·57	4·02	3·80
N	48·98	64·04	46·49
B.T.U. per cu. ft.	160	120	165

The employment of gas for heating steam-boilers is discussed by C. W. Bildt.*

Water-Gas.—E. Demenge† reviews the principal applications of water-gas, and gives several illustrations of Dellwik-Fleischer plant.

The Dellwik-Fleischer and the Strache methods of producing water-gas are described by Placidi ‡ and Kettner.

The relative advantages of coal-gas and water-gas are discussed by A. D. Adams,§ who gives details of the cost of manufacture in Massachusetts. It is said that water-gas can be made at a cost below that of coal-gas, but the actual results in plants of equal capacities are in favour of coal-gas. Low prices are held out as the inducement to adopt water-gas, but consumers get gas cheapest from purely coal-gas plants.

VIII.—*COAL MINING.*

Deep Boring.—The second deepest borehole in the world has just been completed by the Prussian government at Ottweiler near Neunkirchen. It has a total depth of 1803·36 metres. During the boring 27 workable coal-seams and 131 narrow seams were encountered.||

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* *Jernkontorets Annaler*, vol. lix. pp. 190–201.

† *Revue Générale des Sciences*, vol. xv. pp. 71–83.

‡ *Journal für Gasbeleuchtung*, 1904, pp. 168–271.

§ *Mines and Minerals*, vol. xxiv. p. 536.

|| *Chemische Zeitschrift*, vol. iii. p. 598.

P. Stein [*] discusses the method of boring best adapted when a deep hole is to be put down on the incline. Two methods are applicable, one involving rapid percussion with the use of water, and the other of the diamond drill. Rope drilling or the Canadian system would not be applicable, and rotary steel drills would likewise only be employed under exceptional circumstances as the depth of the hole began to increase. The diamond-drill method is best suited for a rock which yields a coherent core. Under such conditions no other method can approach it in value. Coal-seams do not yield such cores, and therefore for these this method loses its special value. Indeed, unless care be taken, seams may be passed through without their presence being observed until the slimes have reached the surface. To avoid this, Köbrich introduced in Prussia an arrangement depending on the fact that the drill passes through coal more rapidly than it does through the rock above and below the seam. As soon, therefore, as it is noticed that the rate of progress has suddenly increased, the diamond drill is stopped and replaced by a hand method until the coal has been pierced. This is not, however, always applicable, and it was not until the rapid percussion method was introduced that this difficulty was overcome. In this latter method a chisel head is used attached to hollow rods. The two are firmly connected, and a series of very rapid blows are given, combined with a very small lift. It is possible to wash out the bored material very rapidly by this method. Indeed, a not over-powerful pump will raise it at a speed of from 200 to 400 yards per minute. The presence of a coal-seam can thus be almost immediately detected. The author briefly sums up his conclusions. The best method, in his opinion, is a combination of the methods just described and that of the diamond drill, so arranged as to enable a dry method to be employed when necessary. Such combined systems are now common.

Underground Temperature.—F. Heinrich [†] has made a mathematical study of the temperature observations at the Paruschowitz borehole. The borehole was sunk to a depth of 2003·34 metres, and the increase in temperature was calculated to be 1° C. for 31·82 metres, whilst at Sperenberg it was 1° C. for 33·04 metres, and at Schladebach 1° C. for 35·46 metres.

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 263–266, 295–298.

[†] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 1–11.

H. Hoefer * discusses the question of underground temperatures, especially in the brown coal-seams of Austria, and considers it to be due to metamorphism and not to hot springs.

Shaft Sinking.—In a Presidential Address to the Engineering section of the British Association, the Hon. C. A. Parsons formulates a scheme for sinking to the depth of 12 miles vertically at a cost of five millions sterling in eighty-five years. The final rock temperature is considered to be 272° C. The shaft is to be sunk in sections, and refrigerating machinery is to be used for transferring heat from each section to the one above it and for cooling the lower sections.

J. R. Wilson † suggests a method of sinking shafts through loose ground to the stone head by a system of piling. Lined boreholes are sunk round the perimeter of the shaft, and as the sinking proceeds the spaces between the borehole linings are wedged.

J. W. Fryar ‡ describes the Sherwood Colliery sinking. In fifty-four weeks a depth of 1302 feet was reached. The top 444 feet, which is coffered and tubbed, occupied thirty-three weeks, including a stop of ten weeks. The remaining 858 feet was sunk and bricked at the rate of 40·8 feet per week. The plant is described, and the discussion turned on questions of power drills, sinking scaffolds, top doors, and other details.

W. O. Wood § described the means adopted for re-tubbing the middle pit at Murton Colliery, County Durham, without interfering with winding operations.

M. Warolus || describes in detail the methods employed in the reconstruction of the 6–7 pit at the Charbonnages de Houssu, in Hainaut, which had become seriously collapsed.

A detailed and fully illustrated account has been published of the Kind Chaudron process of sinking at the Dover Colliery.¶

A. Renier ** gives a series of articles on modern methods of sinking, describing in detail the machinery employed and dealing with all the more recent drills and appliances.

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* *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 351–372.

† *Ibid.*, pp. 86–91.

‡ *Ibid.*, vol. xxvi. pp. 475–493, with plates.

§ *Ibid.*, vol. xxvii. pp. 197–204.

|| *Revue Universelle des Mines*, vol. vii. pp. 200–211.

¶ *Engineer*, vol. xcviii. pp. 175–177, 199–200.

** *Revue Universelle des Mines*, vol. v. pp. 31–78, 125–166, with thirty-one illustrations.

Shaft sinking through the unproductive measures at Aachen is described by Stegemann.*

Freund † describes the collapse of the shaft at the Graf Moltke Colliery during the process of sinking on March 16, 1903.

Prein ‡ describes the method of repairing a caved-in portion of a timber-lined shaft at the Friedrich Wilhelm Colliery, Dortmund.

J. Smeysters § reports that the new ventilating shaft at Marcinelle-Nord has reached a depth of 3360 feet.

R. d'Andrimont ‖ describes the Unger process of sinking to great depths in water-bearing strata.

F. Heise ¶ deals with the strength and dimensions of tubbings required for water-tight shafts.

Adit Levels.—A description has been published ** of the great Gardanne tunnel of the Bouches-du-Rhône Collieries, the total length of which will be 14½ kilometres.

Particulars are given by A. Marcette †† of the great incline at Baudour driven by the Espérance Colliery. The incline is a double one, for haulage and ventilation, at an angle of 20 degrees.

Winding Engines.—R. A. Henry ‡‡ contributes a second instalment of his discussion of the theory and practice of winding engines. The subject is considered in great detail, and copious calculations and formulæ are given.

Illustrations are given §§ of a coupled compound horizontal winding engine designed for a working pressure of 120 lbs. with a cut-off from 85 per cent. to nearly zero. The cylinders are 23 and 37 inches in diameter, with a stroke of 48 inches.

S. L. Thacker ‖‖ deals mathematically with the dynamics of the winding engine, giving calculations for various types of engines and drums. The importance of the weight of the drum is dwelt upon,

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* *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1008–1009.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 195–199.

‡ *Glückauf*, vol. xl. pp. 263–265; *Engineering and Mining Journal*, vol. lxxvii. p. 889.

§ *Annales des Mines de Belgique*, vol. ix. pp. 545–546.

‖ *Revue Universelle des Mines*, vol. v. pp. 209–212.

¶ *Glückauf*, vol. xl. pp. 1293–1299.

** *Moniteur des Intérêts Matériels*, vol. liv. p. 2514.

†† *Ibid.*, p. 2231.

‡‡ *Revue Universelle des Mines*, vol. vii. pp. 1–65.

§§ *Engineer*, vol. xcviii. pp. 180–181.

‖‖ *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 445–474.

and in the discussion, amongst other details, the idea of overbalancing was brought forward.

L. Bresson* enumerates the advantages of automatic cut-off gear, and gives details of experience at the Noeux Colliery.

P. Habets † continues to describe several leading types of winding engines working by electricity. He gives a number of formulæ, showing the behaviour of such engines, and discusses generally the advantages to be derived.

J. H. Merivale ‡ describes the device of T. C. Futers for controlling the steam-valve, brake, and signals of a winding engine to prevent over-winding, and also to prevent starting until the requisite signals are given both at the top and bottom of the shaft.

An electric winding engine of unprecedented size has been installed at the Gelsenkirchen Colliery in Westphalia. Two electric-motors are employed, each of 1400 horse-power; and 1000 tons of coal are hoisted every six hours from a depth of 1650 feet.

Electric winding engines are described by C. Ilgner.§

H. D. B. How ‖ describes two forms of electric winding engines, and compares them with steam winding engines from a mechanical and financial point of view.

W. C. Mountain ¶ gives some notes on electric power as applied to winding in main shafts, and describes the plant at Zollern II. Colliery, Merklinde, and at Preussen II. Colliery near Dortmund.

Further illustrations and details of electric winding machinery are given.**

Laudien †† compares steam and electricity as motive power for driving winding engines.

Winding Appliances.—T. C. Futers ‡‡ continues his series of articles on shafts and headgears for collieries.

A. Forsyth §§ deals with some forms of head frames, and draws

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* *Bulletin de la Société de l'Industrie Minérale*, vol. iii. pp. 217–234.

† *Revue Universelle des Mines*, vol. vi. pp. 258–279.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 484–494.

§ *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereines*, vol. lvi. pp. 377–381, 388–393.

‖ *Proceedings of the South Wales Institute of Engineers*, vol. xxiii. pp. 548–569.

¶ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 142–168.

** *Iron and Coal Trades Review*, vol. lxviii. pp. 1612–1616.

†† *Glückauf*, vol. xl. pp. 616–625.

‡‡ *Colliery Guardian*, vol. lxxxviii. pp. 63, 114, 166, 216, 261, 304, 351, 396, 442, 489, 533, 580, 625, 681, 722, 760.

§§ *Engineering and Mining Journal*, vol. lxxv. pp. 366–371, vol. lxxvii. p. 483.

some comments from H. E. West[*] on the use of timber. W. R. Crane[†] gives an illustrated description of a number of head frames and tipples used in America.

An illustrated description has been published[‡] of the headgear at a shaft of the Albi Collieries. The plant is designed to raise coal in two-deck cages with 4 waggons on each deck from a depth of 500 metres.

C. A. Weck[§] illustrates a head frame for a prospecting shaft.

An elaborate paper on steel mine tipples has been communicated by G. S. Rice[||] to the Western Society of Engineers.

On May 15, 1902, a paper on winding plants for great depths was read before the Institution of Mining and Metallurgy by H. C. Behr. This was discussed in London and by the South African Association of Engineers in Johannesburg. The paper with discussion is now published[¶] in full, the report covering 444 pages, with an atlas of plates. The discussion in Johannesburg turned chiefly on the comparative merits of the drum and sheave systems of winding, valuable details being given regarding cost and efficiency. The author's reply emphasised the value of the cylindro-conical drum, and of taper ropes. The Whiting hoist was considered to be an unnecessarily complicated arrangement.

The limitation of depth in coal-mining is discussed by J. A. Ashworth.[**]

The July number of *Mines and Minerals*[††] is specially devoted to winding problems and appliances. The titles of the articles and their authors are as follows: Balanced and unbalanced hoists, by E. T. Sederholm; relief valves on hoisting engines, by J. J. Rutledge; hoisting engine brakes, by J. S. Lane; portable and self-contained hoists; hoisting engine foundations, by R. V. Norris; hoisting engine foundations, by F. W. Gerecke; compounding in hoisting engines; removing ship boxes from frames, by F. T. Williams; deep hoisting in South Africa, by J. S. Lane; types of hoisting engines, by S. T. Nicholson; care and handling of hoisting engines, by J. H. Penning-

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[*] *Engineering and Mining Journal*, vol. lxxviii. p. 53.

[†] *Ibid.*, pp. 62–65.

[‡] *Echo des Mines*, vol. xxxi. p. 1051.

[§] *Mines and Minerals*, vol. xxv. p. 15.

[||] *Colliery Guardian*, October 7, 1904, *Supplement*, p. 22.

[¶] *Transactions of the Institution of Mining and Metallurgy*, vol. xi. London, E. & F. N. Spon, Ltd.

[**] *Page's Magazine*, vol. iv. p. 528.

[††] Vol. xxiv. pp. 577–638.

ton; hoisting in preliminary mining operations; cylindrical *versus* conical drums, by F. Moeller; electric hoists; some indicator cards from winding engines, by W. A. McLeod; tail or balance rope hoists, by A. H. Storrs; deep hoisting in the Lake Superior district, by O. P. Hood; choice of a hoisting engine; drums *versus* reels, by F. F. Coleman; hoisting engine calculations; gas or liquid fuel hoisting engines, by E. W. Roberts; hoisting engineers' examination paper.

Amongst these papers, especial attention may be drawn to that by E. W. Roberts, who illustrates a gasoline winding engine driven by gasoline at Idaho Springs, Colorado.

A. Lukaszewski * deals with modern methods of winding.

H. L. Auchmuty † discusses the relative advantages of metal grooved and wood lagged drums.

N. V. Hansell ‡ describes the winding arrangements at the Fohnsdorf brown coal mine in Styria.

A compressed air system of signalling in winding shafts is described by B. Macdonald § and W. Thompson.

L. Saclier || describes at some length the appliances at the Arenberg pit belonging to the Société d'Anzin.

F. Mládek ¶ describes the electric signalling appliance for cages designed by W. Oppl. Appliances which necessitate the hand being put outside the cage before it can be operated are dangerous, and many severe accidents have resulted from them. The Oppl appliance was first put into operation at the Lill shaft at Przibram in 1899. As it worked well it was put into use in 1902 at the Anna shaft at Birkenberg where the depth is over 3100 feet, and subsequently at other places that the author names.

Wire Ropes.—Practically the whole of the issue of *Mines and Minerals* for April 1904 ** is devoted to a consideration of wire rope and its uses for wire ropeways, hoisting, &c. A partial bibliography of the subject and a glossary of terms is included. The contents of

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 298–300, 310–313.

† *Mines and Minerals*, vol. xxv. pp. 37–38.

‡ *Bihang till Jernkontorets Annaler*, 1904, pp. 190–193.

§ *Journal of the Canadian Mining Institute*, vol. vi. pp. 161–168; *Iron and Coal Trades Review*, vol. lxix. pp. 697–698.

|| *Revue Universelle des Mines*, vol. v. pp. 196–208.

¶ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 364–365, with four illustrations.

** *Mines and Minerals*, vol. xxiv. pp. 401–462.

the number are as follows: Suspension cableways, by A. Bruch; high-grade wire rope, by L. C. Moore; a new method of testing wires, by A. Falkenau; practical points in the construction and use of wire rope, by L. C. Moore; wire rope haulage problem, by G. S. Whyte; cableways for open pit mining, by S. Miller; wire rope slope haulage; glossary of rope terms; splicing wire rope; the Bleichert ropeway; wire ropeways, by J. H. Janeway; hoisting ropes, by G. S. Whyte; the operation of a wire rope in multiple lap, by W. Hewitt; the transmission of power by wire ropes, by W. H. Graves; effect of bending stresses on wire ropes, by J. B. Richards; history of wire rope; notes on wire ropes, by C. W. Comstock; wire ropeway in Wyoming; wire rope calculations; and wire rope bibliography.

G. W. Westgarth * deals with the various forms of wire ropes from their historical and constructional point of view and with their applications.

Details have been published of the disastrous accident which occurred at the Robinson Deep Mine, on April 25, 1904, when in hoisting a batch of natives the rope broke some 350 feet from the top, and the cage was precipitated to the bottom of the shaft, 2050 feet deep, with the result that 43 were killed. The following are the particulars of the rope, according to the report of the Government Inspector of Machinery, dated May 25: Date of manufacture, August 1903; date supplied, October 1903; length of rope, 2500 feet; construction of rope, flat; size of rope, 6 inches by ⅝ inch; number of strands, 14 ropes each 4 strands; number of wires per strand, 6; diameter of wire, 0·051 inch; class of main core, hemp; class of strand core, hemp; steel of which rope is made, best plough, 105 tons per square inch; breaking load of rope, 113·12 tons (2000 pounds); weight per yard, 15·04 pounds; makers' test of single wires, 672 pounds. The calculated maximum weight at the time of the breakage was 13 tons. The rope apparently broke just when it was going on to the pulley. The weight at which various sections of the rope gave way in the testing machine after the accident varied between 16·39 tons and 115·3 tons, the latter being a section from the drum end. The breaking load of the rope as a whole was calculated at 21·45 tons. The rope was put into work on December 5, so that it had been at work about four and a half months.

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* Paper read before the National Association of Colliery Managers; *Iron and Coal Trades Review*, vol. lxviii. pp. 1286–1288.

The previous rope had been in use over two and a half years. It was usual to take flat ropes off every six months for re-stitching. The rate of winding was said to be limited to 800 feet a minute, and the shaft is an incline one. The evidence showed that the rope was regularly inspected each day, with a fuller inspection on Sundays, and that no signs of deterioration were apparent. On the other hand, apart from the conclusive evidence of accident and the tests, the interior of the rope after the accident showed marked deterioration, certainly for a distance of 600 feet; though whether due to corrosion or wear was not agreed.*

Speer † gives detailed tests of the winding ropes used in Westphalia.

S. Smillie ‡ gives formulæ for determining the sizes of wire ropes.

W. Lockett § records the details of the failure of a locked-coil-winding rope.

C. W. Comstock ‖ also deals with ropes made of vegetable fibre, describing the materials employed, the methods of manufacture and treatment, and the strength and durability under different conditions.

Underground Haulage.—Some illustrations are given ¶ of the main and tail rope haulage plant at the Sherrard Colliery, Illinois.

D. E. Rust ** gives the results of eleven tests on the frictional resistance of tubs with plain and with roller bearings, showing 27·2 and 25·34 pounds per ton respectively.

A. B. Hewitt †† describes an improved roller journal for underground haulage.

W. Hay ‡‡ describes the three-phase haulage plant at Shirebrook Colliery, Mansfield.

B. S. Randolph §§ compares electric and compressed air locomotives in American mines.

Illustrations are given ‖‖ of some early types of electric locomotives for underground use, with particulars of the work done with them in

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* *Mining Journal*, vol. lxxvi. p. 143.

† *Glückauf*, vol. xl. pp. 862–865.

‡ *School of Mines Quarterly*, vol. xxv. pp. 194–198.

§ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 254–262.

‖ *Mines and Minerals*, vol. xxiv. pp. 530–532.

¶ *Iron and Coal Trades Review*, vol. lxix. pp. 621–623.

** *Mines and Minerals*, vol. xxv. pp. 49–50.

†† *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 319–321.

‡‡ *Ibid.*, pp. 282–289.

§§ *Ibid.*, pp. 429–442.

‖‖ *Mines and Minerals*, vol. xxiv. pp. 374–375.

the United States. W. L. Affelder[*] deals generally with more modern types, working with trolley wires, third rails, and rack rails.

H. M. Warren[†] gives some details of the underground use of electric locomotives.

Various types of electric mine locomotive are described by Buhle.[‡]

An electric hauling winch made by Chambers, Scott, & Co., is figured and described,[§] capable of hauling trucks loaded to 60 tons, at a speed of two miles per hour upon a level track.

Lining Shafts with Concrete.—A description is given[‖] of a rectangular shaft lined with concrete. The shaft is 50 feet long by 12 wide in the clear and is lined to a depth of 40 feet on one side and 20 to 25 feet on the other side with concrete, 4 feet in thickness. The material was mixed on the surface and delivered by shoots. The buntons are also of concrete, strengthened by a 65-lb. rail. Tubes are inserted in these buntons to hold the guide-rod bolts.

F. B. Villasante[¶] has successfully employed armoured cement for lining the Vizcaya shaft at Mazarron. The blocks measure 0·20 by 0·50 by 0·34 metres, and were made in wooden moulds at the shaft, to suit the section of the shaft which is circular and 3·5 metres in diameter. Each block weighs 70 kilogrammes.

Mine Supports.—A series of experiments are given by N. I. Crahay,[**] on the strength and durability of mine timber, (1) in its natural state, and (2) with the bark removed. He finds the results wholly in favour of the naked timber, which is lighter, less bulky, stronger, and more durable. This is particularly the case in regard to larger timber. With small timber the expense of removing the bark may sometimes be greater than the saving in other respects.

S. P. Sadtler[††] describes the various methods used for the preservative treatment of wood.

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[*] *Mines and Minerals*, vol. xxiv. pp. 380–386.

[†] *Ibid.*, p. 529.

[‡] *Dinglers Polytechnisches Journal*, 1904, pp. 156–159.

[§] *Engineer*, vol. xcviii. p. 297.

[‖] *Engineering and Mining Journal*, vol. lxxvii. pp. 646–647.

[¶] *Revista Minera*, vol. lv. p. 427.

[**] *Bulletin de la Société Centrale forestière de Belgique; Revue Universelle des Mines*, vol. vi. pp. 206–215.

[††] *Technology Quarterly*, vol. xvii. pp. 129–144.

The Powell wood process of seasoning pit props is described and figured.[*] In this system the timber is treated with a solution of saccharine, a cheap form of molasses being used.

The use of telescopic iron tubes as a substitute for mine timber is described by F. Sommer.[†]

R. V. Norris[‡] gives particulars of steel supports used in Pennsylvanian collieries, and adds some tables on the strength of various sizes of timbers, of steel girders, and props.

Illustrations are given[§] of the Mannesmann weldless steel pit prop.

S. Hare[‖] describes the methods of using steel girders at the Murton Colliery, and also a machine for straightening them when they have become bent in use.

H. S. Smith[¶] discusses the systematic withdrawal of timber in the collieries in Somersetshire.

Electricity in Mines.—The Engineering Standards Committee have issued an interim report on generators, motors, and transformers. Standard pressures, frequencies, methods of working the machines, speeds, and horse-powers are specified, so as to reduce the number of machines kept in stock.

It has been decided that no attempt should be made to prescribe standard dimensions or shapes which might hamper future development in design, but to confine the recommendations to such points as would ensure uniformity in nomenclature, outputs, and test conditions.[**]

A. Lukaszewski[††] observes that almost every new technical improvement utilised in mining brings with it some new danger. Thus, for instance, electricity, dangerous enough already above ground, is infinitely more so when employed below ground where half the isolations at surface are either useless or soon become so. Taking a wire to earth in the mine is not an easy matter. Simply inserting it in the ground is there no longer adequate, as the resistance of the miner's body, with

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[*] *Iron and Coal Trades Review*, vol. lxix. pp. 1341–1342.

[†] *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 137–142.

[‡] *Engineering and Mining Journal*, vol. lxxviii. pp. 60–61.

[§] *Iron and Coal Trades Review*, vol. lxix. p. 256.

[‖] *Ibid.*, p. 406.

[¶] *Ibid.*, p. 551.

[**] "British Standards for Electrical Machinery," 1904. Price 2s. 6d. (London: Crosby Lockwood & Son.)

[††] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 342.

hands and clothes wet, and standing on wet ground or on rails, is then far less than it is under different conditions at surface. The wire to be earthed must therefore terminate in earth plates of large surface area. The author also deals with the effect of the electric current on the human body, and the means to be taken to endeavour to restore animation after electric shock.

The applications of electricity in mines are described by E. Kolben.*

The applications of electricity in the working of coal-mines are described by E. Gevers-Orban.†

W. Maurice ‡ offers some comments on the proposed rules for the installation and use of electricity in mines. S. F. Walker § also deals with this matter.

R. Holiday ‖ compares three-phase and continuous currents for mining purposes.

C. S. V. Brown ¶ gives an illustrated account of central electric generating plant at Belgian and German collieries.

At collieries at Tingley, near Leeds, the electric-generating plant is driven by gas-engines supplied with coke-oven gas, each engine being of 250 horse-power.**

L. de Charentenay †† describes the electric plant at the Mure anthracite mines, Isère, France. Electric winding engines and mine locomotives are used.

Huber ‡‡ discusses the employment of electrical machinery in mines. The paper is mainly directed to a discussion of the relative advantages of distribution by direct current with accumulators and three-phase systems.

Compressed Air in Mines.—Illustrations are given §§ of a compressed air plant and the scheme of transmission in a large open working.

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* *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 201–205.

† *Engineering Press Monthly Index Review*, July 1904, pp. 1–6.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 290–318.

§ *Ibid.*, pp. 388–409.

‖ *Ibid.*, pp. 410–428.

¶ *Cassier's Magazine*, vol. xxvi. pp. 243–256.

** *Iron and Coal Trades Review*, vol. lxix. p. 545.

†† *Bulletin de la Société de l'Industrie Minérale*, vol. iii. pp. 79–117.

‡‡ *Glückauf*, vol. xl. pp. 1276–1278; translation in *Mining Journal*, vol. lxxvi. p. 431.

§§ *Mines and Minerals*, vol. xxv. pp. 17–19.

A report on trials of air-compressors in the Dortmund district has been published.*

The experience of A. Sohier † and G. Massart of the Nord de Flénu Colliery at Ghlin regarding the use of compressed air for underground haulage has been recorded. The irregularities in the levels, springs of water, and shifting ground render endless chain and electric haulage inapplicable, and consequently high tension compressed air is used, with the result that eighty-five horses, fourteen grooms, and fifty drivers have been replaced by twelve compressed air locomotives, costing 10,000 francs apiece. The whole installation cost 280,000 francs, and allowing 10 per cent. for interest and depreciation, the new haulage costs 81,000 francs per annum instead of 139,400 francs with horse haulage.

J. Diviš ‡ describes an air-compressor which has been erected at the St. Pancras Colliery at Nürschau. The old fashioned one-stage dry compressors in former use there caused much difficulty. When in active operation, the temperature of the air rose to 300° C., and then even the most expensive lubricating oils were of no use. A compound three-stage compressor capable of dealing with about 2100 to 2400 cubic feet of air per minute has now been erected.

Explosives and Blasting.—O. Guttmann § gives an interesting note on the history of gunpowder. A list of the hitherto known manuscripts and references, which carries back the date of its use to 1338, is now antedated by twelve years to 1326. An illuminated manuscript shows the figure of a bottle-shaped gun shooting an arrow and ball and provided with a touch-hole.

A. Mikolajczak ‖ describes some new explosives, of which dinitroglycerine is the base.

C. E. Bichel ¶ discusses the ignition of firedamp by detonating explosives.

Recent improvements in explosives and blasting are described by P. Hess.**

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* *Glückauf*, vol. xl. pp. 625–629.

† *Moniteur des Intérêts Matériels*, vol. liv. p. 1945.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 81–85, with five illustrations.

§ *Journal of the Society of Chemical Industry*, vol. xxiii. pp. 591–592.

‖ *Glückauf*, vol. xl. pp. 629–630.

¶ *Ibid.*, pp. 1040–1048.

** *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 103–136.

W. Denker * discusses mine accidents caused by blasting.

N. Hake † gives a method of detecting defective places in fuses by means of Röntgen rays, and thus of avoiding misfires.

According to the report on the work carried on at the Home Office testing station in 1903, some tests have been made on wax as a substitute for paper wrappings, on the effect of cold on ammonium nitrate explosives, and on detonators.

V. Watteyne ‡ deals with the work of the government experimental station at Frameries, Belgium, with explosives.

Coal Cutting.—F. C. Swallow § gives some notes on coal-mining in Warwickshire, with special reference to the use of the Stanley coal-heading machines in the rapid development and working of the Nuneaton Colliery.

A. J. Tonge || gives the results obtained at the Hulton Collieries, with various types of electrically driven coal-cutting machinery in seams varying from 1⅔ to 3½ feet in thickness. A saving in cost and in the amount of round coal produced is shown.

W. E. Garforth ¶ deals with the application of coal-cutting machinery to deep mining.

A. S. E. Ackermann** describes various types of British and American coal-cutting machines, and gives some details of their use. A table of the weights, sizes, and performances of known makes is appended.

G. L. Kerr †† deals at some length with heading, disc, chain, bar, and percussive types of coal-cutting machinery, giving illustrated accounts of their performances.

R. Rieger,‡‡ in a paper read before the Mining and Metallurgical Society, Moravian-Ostrau, describes the results that have been obtained with a mechanical coal getter of the Jeffrey type at the

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* *Glückauf*, vol. xl. pp. 785–793.

† *Bergbau*, August 18, 1904, p. 9.

‡ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 445–456.

§ *Ibid.*, vol. xxvi. pp. 530–551.

|| *Transactions of the Manchester Geological and Mining Society*, vol. xxviii. pp. 354–369.

¶ Paper read before the National Association of Colliery Managers; *Iron and Coal Trades Review*, vol. lxviii. pp. 1440–1444.

** Paper read before the Society of Engineers; *Iron and Coal Trades Review*, vol. lxviii. pp. 1541–1542.

†† *Iron and Coal Trades Review*, vol. lxviii. pp. 2021–2029.

‡‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii.; *Beilage*, No. 5, p. 32.

Louis pit at Witkowitz. The results attained have, indeed, been so successful during the year the machine has been at work that its use is thought to have solved the problem of the best method of winning the coal from the poorer seams of the Witkowitz field.

In the discussion which ensued on the reading of this paper, an account was given by Mayer [*] of similarly good results obtained at the Jacob pit belonging to the K. F. North Railway with a similar type of machine on the Staněk and Reska system. An account of the diamond form of this kind of coal getter was also described by J. Popper,[†] who considers it to possess various advantages over the Jeffrey machine. Details are given as to the results that have been obtained with it in the same neighbourhood.

Methods of Working.—H. W. G. Halbaum [‡] deals comprehensively with the action, influence, and control of the roof in longwall workings.

The methods of working coal in the Rhenish Westphalian basin are described by M. Bodart.[§] An abstract has also appeared.[||]

A. Lukaszewski [¶] deals generally with modern methods of ore and coal-mining. Mechanical coal getters, the various kinds of rock drills, and the methods of shot-firing are passed in review. The author then deals with timbering, shaft sinking, ventilation, methods of general mining, and the filling of worked-out spaces by water-borne material.

A novel method of reducing the cost of working and winding coal is proposed by P. Beau.[**] He recommends that the coal in the mine should be systematically burned and converted into gas.

K. Yonekra [††] describes the collieries in Hokkaido at Sorachi and Yubari, giving an illustrated description of the ventilation, haulage, and other plant.

B. S. Lyman [‡‡] gives an illustrated account of the Miike and other Japanese collieries.

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[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii.; *Beilage*, No. 5, pp. 32–33.

[†] *Ibid.*, pp. 33–34.

[‡] *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 205–228.

[§] *Annuaire de l'Association des Ingénieurs sortis de l'École de Liége*, vol. xvii. pp. 177–242; *Revue Universelle des Mines*, vol. v. pp. 271–307; vol. vi. pp. 1–29.

[||] *Iron and Coal Trades Review*, vol. lxviii. pp. 1688–1690.

[¶] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 221–225, 241–244, 255–256, 271–273, 279–283, 298–300, 310–313, 323–326, 341–343.

[**] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1904, pp. 136–140.

[††] *Mines and Minerals*, vol. xxiv. pp. 349, 508, 533.

[‡‡] *Engineering and Mining Journal*, vol. lxxviii. pp. 142–144.

Witte [*] discusses the possibility of obtaining, by hydraulic works on a large scale, sand for filling colliery workings by the flushing process in Upper Silesia.

Sternberg [†] describes the flushing method of filling-in old workings in Upper Silesia, Moravia, and Poland.

Mine Drainage.—O. E. Westin [‡] gives descriptions and illustrations of the colliery pumps used in the Dortmund district. Illustrations are given of the Riedler pump, of the Riedler express pump, of Ehrhardt and Sehmer's express pump, of Klein's express pump, of the Frankenthal express pump, of the Grevenbroich express pump, of the high-pressure centrifugal pump of Sulzer Brothers, of the Kaselowsky-Prött hydraulic pump, and of the Mammoth pump.

G. Baum [§] traces the recent developments in mine drainage.

The design of compound tandem pumping engines is discussed by J. Farkas.[||]

The report [¶] of the South Staffordshire Mines Drainage Commission shows that in 1903 forty tons of water had been raised in the district for every ton of mineral, at a cost of 0·23d. per ton of water raised.

Some old types of pumping engines in use are described [**] and figured, special mention being made of an engine at Redruth, and a condensing beam engine made in 1841, used at Ventwin Mine, near St. Austell, for driving a pump.

An illustration is given [††] of one of a number of winding engines used in the Pennsylvanian anthracite region for winding water. It consists of a pair of 36 by 60 inch cylinders driving a conical drum. The tanks hold 2600 gallons. From a two-compartment shaft, 1500 feet in depth, 3,500,000 gallons are raised in twenty-four hours.

R. V. Norris [‡‡] gives an illustrated account of the methods of winding water in the Pennsylvanian anthracite region. Sections of several forms of the tanks are given.

G. A. F. Ahlberg [§§] deals generally with pumps and pumping

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[*] *Zeitschrift des Oberschlesischen Berg- und Hüttenmännischen Vereins*, 1904, pp. 265–268.

[†] *Glückauf*, vol. xl. pp. 1300–1305.

[‡] *Bihang till Jernkontorets Annaler*, 1904, pp. 39–70.

[§] *Glückauf*, vol. xl. pp. 1005–1012.

[||] *Banyaszati es Kohaszati Lapok*, vol. xxxvii. pp. 42–49.

[¶] *Colliery Guardian*, vol. lxxxviii. p. 686.

[**] *Engineer*, vol. xcviii. p. 364.

[††] *Engineering and Mining Journal*, vol. lxxvii. p. 567.

[‡‡] *Cassier's Magazine*, vol. xxvi. pp. 48–59.

[§§] *Proceedings of the Engineers' Society of Western Pennyslvania*, vol. xix. pp. 47–865.

machinery, incidentally treating of mine pumps, and giving a table of the duty and efficiency of various types.

A view is given * of a horizontal pumping engine designed to lift 60,000 gallons hourly against a head of 1080 feet with 70 lb. steam pressure.

High-pressure centrifugal pumps are described by H. Dubbel,† and by K. Sosnowski ‡ (De Laval type).

Some tests of high-speed centrifugal pump working in series have been made by J. E. Denton and W. Kent, and the results have been published.§

L. Masson ‖ contributes a lengthy report upon a communication made by K. Sosnowski upon high-pressure De Laval centrifugal pumps. The behaviour of turbine pumps installed at the Mines de Lens is recorded, with diagrams, and a description of electric pumps working on this system is given.

A description is given by Rey ¶ of multicellular pumps working on the Rateau system.

A. Rateau ** contributes a note on the use of steam accumulators for exhaust steam as used at collieries.

J. Diviš †† discusses the use of high-pressure centrifugal pumps and fans on the Rateau system. At the Elizabeth shaft at Schatzlar an electric-driven pump of this kind has been successfully in use for over a year. It has about 65 per cent. effective power and, making 1500 revolutions in the minute, raises 2400 litres of water to a height of 150 metres. A current of 530 volts and 95 ampères is employed. This is a Sulzer pump. A similar pump on the Rateau system has been put into operation at the Bernhard shaft near Falkenau. It is operated by a Rateau steam turbine and lifts 461 litres of water per second through a height of 232 metres, the pump making 3350 revolutions per minute, an absolute steam pressure of 7·6 atmospheres being employed. With an effective power of 142·5 horse-power only 12·9 kilogrammes of steam per effective horse-power is required. The

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* *Iron and Coal Trades Review*, vol. lxix. p. 477.

† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1003–1006.

‡ *Memoires de la Société des Ingénieurs Civils de France*, 1904, No. 1, pp. 233–241.

§ *Engineering News*, vol. li. pp. 512–514.

‖ *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. cvi. pp. 407–429, with seventeen illustrations.

¶ *Ibid.*, pp. 430–452, with seventeen illustrations.

** *Revue Universelle des Mines*, vol. v. pp. 17–30.

†† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 331–335, 349–353, with eight illustrations.

author, struck by this result, has made inquiries as to the results obtained with these Rateau high-pressure pumps elsewhere, fans being also dealt with. These he now discusses in detail, as well as the appliances themselves.

W. Boveri [*] deals at considerable length with steam turbines and their uses, devoting particular attention to the Parsons type. The growing use of this form of machine is referred to by the author, who states that his firm alone has already delivered to works on the Continent of Europe sixty such machines, with a total horse-power of 50,000. The total orders so far received have been for 190 of these steam turbines, with a total horse-power of about 225,000. The average horse-power for each is thus about 1000. Of these turbines, however, 6 are to be each of from 8000 to 10,000 horse-power, which considerably lowers the average for the remainder.

Mentzel [†] gives an account of the difficulties caused by the occurrence of water containing barium and sulphuric acid at the De Wendel Colliery at Hamm.

The Ventilation of Collieries.—M. Deacon [‡] gives the results of some comparative tests on Waddle and Capell fans working on the same colliery.

A. Lukaszewski [§] deals briefly with modern methods of ventilation employed in collieries.

Illustrations are given [‖] of an electrically-driven Sirocco fan, and of the arrangements of drifts for replacing two Guibal fans working on two shafts by a single fan.

Illustrations are given [¶] of the Sirocco fan at the Pelton Colliery, Durham, to show the setting and form of the blades.

F. Collischonn [**] describes the electrically-driven ventilating plant at the Nothberg Colliery of Eschweiler Company.

Grahn [††] describes the air-lock at the ventilating shaft of the Deutscher Kaiser Colliery at Hamborn.

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[*] *Stahl und Eisen*, vol. xxiv. pp. 737–756, with twenty-one illustrations.

[†] *Glückauf*, vol. xl. p. 1012.

[‡] *Transactions of the Institution of Mining Engineers*, vol. xxvi. p. 517.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 324–326, with one illustration.

[‖] *Engineer*, vol. xcvii. p. 642.

[¶] *Engineering and Mining Journal*, vol. lxxvii. pp. 608–609.

[**] *Glückauf*, vol. xl. pp. 822–827.

[††] *Ibid.*, pp. 713–716.

E. Lagage [*] details a series of trials made at the Charbonnages de Fontaine l'Evêque on the efficiency of large Guibal ventilating fans.

Firedamp Explosions.—M. G. Moore [†] gives a detailed account of the firedamp explosion at the Rolling Mill mine, Johnstown, Pennsylvania, on July 10, 1902, which resulted in the loss of 112 lives.

A. Iznardi [‡] and E. Jubes describe the explosion at the La Reunion Colliery on April 22, 1904. A detailed description of the colliery is given, showing that it is well equipped, and well ventilated. Indeed, during the past five years the death rate from accident in mines in Spain averaged 3·71 per 1000, whilst that at the La Reunion Colliery was 2·78 per 1000, or 25 per cent. less. The accident was caused by the opening of a safety-lamp.

F. Heinrich [§] deals with accidents in mines, giving in tabular form details of all the great mining catastrophes from 1710 to 1903.

Knochenhauer [||] describes some recent notable explosions in the coal-mines of Upper Silesia.

Laying Dust in Collieries.—An illustration has appeared of a new design of spraying tank for use in dusty mines. The tank is charged with water and with air under pressure. [¶]

The Lighting of Collieries.—Various patterns of portable electric lamps for use underground are described by E. Cuvelette. [**]

A. Bohres [††] describes an electric lamp, which weighs about 4 lbs., and is consequently only very slightly heavier than the ordinary benzine lamp. It has a single accumulator, which gives a light equal to about twice that of the ordinary benzine lamp for a period of 9·5 to 10 hours. The charging opening of the accumulator is so closed by a screw arrangement as to cause the gases to escape in a dry condition, and consequently without their being dangerous

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[*] *Revue Universelle des Mines*, vol. vii. pp. 99–105.

[†] *Journal of the Franklin Institute*, vol. clviii. pp. 81–96.

[‡] *Boletin Minero*, vol. vii. pp. 245–247.

[§] *Banyaszati es Kohaszati Lapok*, vol. xxxvii. pp. 217–243.

[||] *Glückauf*, vol. xl. pp. 1373–1384.

[¶] *Iron and Coal Trades Review*, vol. lxix. pp. 185–186.

[**] *Bulletin de la Société de l'Industrie Minèrale*, vol. iii. pp. 185–216.

[††] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 303–305, with two illustrations.

to the metal parts. No acid can escape if the lamp is held on the slant. The lamp is made in two patterns, one arranged for the light being upwards, and in the other the lamp is at the bottom, and the accumulator above it. The outer glass of the lamp is exposed freely, and can be readily cleared from dust by a cloth. Between this outer glass and the inner glass of the lamp proper is an air-tight space filled with air. Owing to the heat of the lamp this attains a higher tension than that of the outside air, and if both the outer and inner glasses are broken, this imprisoned air streaming out in the one direction tends to prevent an inrush of explosive gas, while entering the inner lamp on the other it almost instantaneously destroys the carbon thread. The Osmium lamp is the one employed. This needs a current of only about 2 volts, which not only renders it much safer, but also admits of the use of a single-cell accumulator. The Osmium lamp has the disadvantage that the carbon filament is very brittle. This is only true, however, of the lamp when it is not alight. So soon as the filament is at a red heat, it is only very slightly affected either by a blow or by being shaken. It is therefore necessary that the lamp should be lit before being handed to the miner. Of a series of lamps submitted to experiment, more than one-half remained alight for over 800 hours; but, assuming an eight-hour shift, with a nine-hour light for this, and a life of 300 hours per lamp, the author shows that the electric lamp, if anything, will cost somewhat less to use and to keep up than the benzine safety-lamp, while the light given will be twice as great.

A. Lukaszewski * observes that although no final experiments have yet been made with the acetylene safety-lamp, it is evident that it is a valuable appliance, yielding, as it does, a light some six to eight times as great as that of the ordinary safety-lamp. It is consequently of much value in the lighting of lofty spaces, &c. Electric lighting is being steadily introduced in connection with the main haulage ways and other important permanent portions of the colliery. Safety-lamps are being perfected in various ways, and these the author indicates. He also refers to the use of the Bear-Mackie lamp, for the determination of the gas present in the air in collieries. This, he states, consists in an ordinary safety-lamp, in which, near to the flame, two vertical wires are fixed. At right angles to these, at a height corresponding to the gas contents of the air entering the lamp, are placed a number of thin platinum wires. The flame of

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 323–324.

the lamp is small and carefully regulated. As the gas contents of the air increases, so too does the length of the flame, which in turn renders incandescent one platinum wire after the other. The number of platinum wires so rendered incandescent shows the gas contents of the air. Electric lamps for colliery use, as replacing ordinary safety-lamps, are also briefly referred to.

V. Watteyne[*] deals with the work of the Government experimental station at Frameries, in Belgium, with safety-lamps.

Underground Fires.—F. W. Hardwick[†] gives the causes of underground fires as due to accidental and spontaneous ignition, the various causes being classified in detail. Systems of prevention are then discussed. A list of accidents and a bibliography of the subject are appended.

G. E. Lawton[‡] deals with the same subject, especially with reference to fires in seams in the North Staffordshire field.

Brauns[§] describes the origin and prevention of mine fires caused by the spontaneous combustion of coal in the Zwickau district of Saxony. Drawings are given of the various forms of mine-dam used.

Camus[‖] advocates the use of liquid carbonic anhydride for extinguishing mine fires.

W. Kummer[¶] describes a method of fighting fires with milk of lime.

Jaekel[**] describes the mine fire at the Ficinus pit of the Laurahütte Colliery in Upper Silesia on September 26, 1903.

Life-Saving Appliances.—Schulte[††] describes some new types of rescue apparatus for colliery use.

Wanz[‡‡] describes a new form of breathing apparatus for rescue purposes.

G. A. Meyer[§§] describes the rescue appliances used at the Shamrock Colliery.

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[*] *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 445–456.

[†] *Ibid.*, vol. xxv. pp. 724–748.

[‡] *Ibid.*, vol. xxvii. pp. 109–124.

[§] *Glückauf*, vol. xl. pp. 609–616, 677–683.

[‖] *Bergbau*, August 11, 1904.

[¶] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 183–185.

[**] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 264–269.

[††] *Glückauf*, vol. xl. pp. 655–658.

[‡‡] *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. lvi. p. 490.

[§§] *Glückauf*, vol. xl. pp. 1125–1164.

J. Mayer * discusses various life-saving appliances and their use in the Ostrau-Karwin district. The Wanz oxygen appliance is also described. He also states that he suggested the erection of underground life-saving stations so far back as 1878, and subsequently introduced them. At the collieries of the Kaiser Ferdinand North Railway a series of life-saving stations have been established below surface. In all seventeen of these have been erected, and they have been equipped with 26 Walcher and 12 Neupert safety-breathing appliances, which are always ready for immediate use, being frequently exchanged for others kept at the surface. They are kept in air-tight sheet-metal cases. The author gives the rules in use at the collieries referred to in connection with these stations and the life-saving methods employed. A list of the supplies to be kept at each is also given. Each chamber is provided with a separate supply of air brought in under pressure. By turning on a tap this air-supply becomes at once available. The station is provided with double air-tight doors with small windows of thick glass, and is so arranged as to remain as far as possible intact after an explosion. The men are required to hasten to these stations, and to remain there until help reaches them or until the ventilation has been restored. The first workman who reaches the chamber is required to light it up, or to hang an electric lamp outside it as a guide to the rest of the men. Each chamber is provided, in addition to its other supplies, with water, wine, brandy, and vinegar.

History of Coal Mining.—J. H. Jackson † gives some notes on early mining in Staffordshire and Worcestershire.

A. Lukaszewski ‡ reviews the condition of mining engineering at the end of the year 1903.

The old colliery pumping engine at Höganäs, Sweden, one of the greatest achievements of Samuel Owen, is described by H. A. Mueller.§ Numerous old dimensioned drawings are reproduced.

The old mining laws of Bohemia, Moravia, and Silesia in the seventeenth, eighteenth, and nineteenth centuries are summarised by Josef Lowag.‖

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* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 361–364, 379–383, 394–397, 410–413, with ten illustrations.

† *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 98–107.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 209–211, 221–225, 241–244, 255–256, 271–273, 279–283, 298–300, 310–313, 323–326, 341–343.

§ *Jernkontorets Annaler*, vol. lix. pp. 154–189.

‖ *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 433–438.

In a recent judicial case, the definition of the term goaf or gob came into question. In his judgment F. W. Raikes* stated that it was no doubt correct to say that the "goaf" was that part of the mine from which all the coal had been extracted, but that was by no means the same proposition as that all space from which the coal had been extracted was goaf, and the term required some limitation.

Mine Surveying.—W. Lenz † gives a brief summary of the development of mine surveying in the Ruhr coalfield.

Under the name of clinocompass, J. Blaas ‡ describes a combined miner's hanging compass and clinometer specially devised for geological work.

C. E. Morrison § describes a convenient form of back sight for underground surveys. It consists of a candle lamp, with a sighting wire, weighted to hang vertically.

A. F. Eoll || describes the Hammer-Fennel tachymeter-theodolite.

The bars of *invar* metal (64 per cent. of steel and 36 per cent. of nickel), used for base measuring by the French geographical service, are described by R. Bourgeois.¶

According to G. Lippman ** the alloy of nickel and iron known as *invar*, which possesses a coefficient of expansion only one-twentieth that of brass, has obvious advantages for pendulum observations. This steel, however, is magnetic, and it was thought possible that the disturbing influence introduced in this way might be too large to be neglected. The magnetic moment of a tube of this material was determined, and the possible error on the pendulum observation calculated. It was found to be negligible, and hence *invar* can be advantageously substituted for brass in the pendulum.

The use of nickel-steel alloys in the measurement of geodetic base lines is described by P. Pizzetti.††

The determination of the share of damage to the surface of two adjacent mines is discussed by Kampmann. ‡‡

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* *Colliery Guardian*, vol. lxxxvii. p. 1087.

† *Die Entwicklung des Niederrheinisch-Westfälischen Steinkohlenbergbaues*, vol. i. Berlin, 1904.

‡ *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. pp. 453–458.

§ *Mines and Minerals*, vol. xxv. p. 10.

|| *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 373–387.

¶ *Revue générale des Sciences*, vol. xv. pp. 376–386.

** *Comptes Rendus*, May 2, 1904.

†† *Il Nuovo Cimento* (Pisa), vol. vi.

‡‡ *Glückauf*, vol. xl. pp. 959–962.

Sanitation in Collieries.—The subject of sanitation in mining and metallurgy is discussed by V. Korbelius.*

The Report on the Health of Cornish Miners, by J. S. Haldane, J. S. Martin, and R. A. Thomas, has now been published as a Blue Book. This report deals extensively with phthisis and its origin in the dust from rock drilling by machinery in dry holes.

A leaflet, prepared by F. Brain, on the prevention of ankylostomiasis, and circulated in Gloucestershire by the police, has been published.† E. M. Heppel ‡ discusses the spread of the disease. The subject was also discussed at the Cambridge Meeting of the British Association.§

A report to the Secretary of State for the Home Department on "The Diagnosis of Ankylostoma Infection, with Special Reference to the Examination of the Blood," by A. E. Boycott, Gordon Lecturer on Experimental Pathology in Guy's Hospital, has just been published as a Parliamentary paper (Cd. 2066, price 1½d.).

J. Mayer ‖ deals with ankylostomiasis at the George Colliery in Moravian Ostrau, and in the Ostrau-Karwin district generally. The life of the worm is believed to be about six years.

The Colliery Exhibition.—The second colliery exhibition ¶ was held in London at the Agricultural Hall in July 1904, and the various technical papers have devoted a considerable amount of space to illustrated descriptions of the machinery. Amongst them were a good representation of electrically-driven, winding, hauling, pumping, and coal-cutting machinery.

IX.—*COAL WASHING AND SCREENING.*

Surface Arrangements.—M. Deacon ** gives some notes on the surface and other plant of the Glapwell Colliery, Derbyshire.

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* *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 173–182.

† *Colliery Guardian*, vol. lxxvii. p. 1297.

‡ *Iron and Coal Trades Review*, vol. lxix. p. 551.

§ *Ibid.*, p. 624.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 235–237, 252–254, and 267–271.

¶ *Engineer*, vol. cxvii., supplement, June 21, 1904, pp. xvi.; *Iron and Coal Trades Review*, vol. lxviii. pp. 1997–2016; *Colliery Guardian*, vol. lxxxviii., supplement, July 1, 1904, pp. xxiv.

** *Transactions of the Institution of Mining Engineers*, vol. xxvi. pp. 512–529.

G. W. Harris[*] gives a detailed account of the surface plant of a colliery at Ernest, Indiana County, Pennsylvania. R. M. Hosea[†] gives a similar account of a colliery at Primero, Colorado.

Further instalments of the series of articles of the mechanical engineering of collieries by T. C. Futers,[‡] have appeared. The subjects now under consideration being surface arrangements, and head gear.

G. S. Rice deals with the use of steel for coal-mine tipples, and gives an illustrated account of the Cardiff plant, Illinois.

G. H. Winstanley[§] deals with the mechanical equipment of collieries, and ranges generally over the progress and present condition in various departments.

Coal Screening.—A plan and some illustrations are given of the coal screening and belt picking plant at the Douglas Bank Colliery, Wigan.[‖]

Particulars have appeared[¶] of the screening and picking plant at Mirfield Colliery, Ravensthorpe.

An illustration is given[**] of the new breaker in course of erection at the Nottingham shaft, Plymouth, Pennsylvania. It contains twenty-four jigs.

F. E. Saward[††] gives some particulars from a recent report on the Girard estate to show the percentages of different sizes of anthracite produced from the mines and from the reworking of the old culm banks. Last year about equal quantities of large and small sizes were made from all sources, but of that from mining, excluding the culm banks, the large sizes were double the quantity of the small.

Coal Washing.—Illustrations are given of the coal-washing plant at the Great Western Colliery, Pontypridd. In the fine coal jigs terra-cotta is used instead of felspar.[‡‡]

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[*] *Mines and Minerals*, vol. xxiv. pp. 465–473.

[†] *Ibid.*, pp. 521–526.

[‡] *Colliery Guardian*, vol. lxxxvii. pp. 1122, 1175, 1245, 1280, 1336; vol. lxxxviii. pp. 15, 63, 114, 166, 216, 261, 304, 312, 351, 396, 442, 489, 533, 580, 625.

[§] *Transactions of the Manchester Geological and Mining Society*, vol. xxviii. pp. 422–452.

[‖] *Iron and Coal Trades Review*, vol. lxix. pp. 473–475.

[¶] *Engineer*, vol. xcviii. p. 181.

[**] *Engineering and Mining Journal*, vol. lxxviii. p. 24.

[††] *Iron Age*, April 28, 1904, pp. 6–7.

[‡‡] *Iron and Coal Trades Review*, vol. lxviii. pp. 1438–1439, 1542.

An illustrated article on the new coal-washing plant of the Roechling steelworks at Voelklingen has been published.* A month's trial with coal averaging 21 per cent. of ash gave 75 per cent. of coking coal, with 6·5 per cent. of ash, 21 per cent. of shale with 68 per cent. of ash, and 4 per cent. of slimes with 38 per cent. of ash. The yield of coke was 56 per cent., with 10·5 per cent. of ash.

A description has been published † of the new screening and washing plant at the Dahlbusch Colliery.

C. Blömeke ‡ discusses the various systems of coal washing and classification exhibited at the Düsseldorf Exhibition.

W. McD. Mackey § deals with slack washing and preliminary treatment for the extraction of fine dust so as to avoid the difficulties arising from the re-use or purification of the water used for washing. The use of an inclined canvas belt is suggested. The finer material adheres to the belt, while coarser material runs off if a thin stream of the raw slack is fed on to it. Separation by an air blast and other methods are mentioned in the discussion.

F. Blanc || discusses the definition of coals and their modifications by washing.

W. McD. Mackey ¶ generally but briefly deals with the problems of washing coal, and gives some notes on the laboratory examination of coal to be used.

R. M. Hosea ** describes in detail the coal-washing plant at Segundo, Colorado, giving a number of illustrations. Jigs are employed.

W. R. Crane †† describes the coal-washing plant at Howe, Indian Territory, for supplying beehive ovens. Campbell shaking tables are used, working at 60 to 70 strokes of 4 to 6 inches per minute.

Illustrations are given of the McLellan coal washer which is of the inclined trough type, with two troughs on either side of a central trough in which a screw conveyer runs to discharge the dirt at the top, the dirt being passed to the centre from the side troughs by arms on revolving shafts, while the coal flows downwards. ‡‡

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* *Glückauf*, vol. xl. pp. 586–591.

† *Ibid.*, pp. 658–660.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 289-293, 305-309, with one plate.

§ *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 55–62.

|| *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1904, pp. 96–100.

¶ *Journal of the Society of Chemical Industry*, vol. xxiii. pp. 431–433.

** *Mines and Minerals*, vol. xxv. pp. 4–10.

†† *Ibid.*, vol. xxiv: pp. 371–374.

‡‡ *Iron and Coal Trades Review*, vol. lxix. pp. 413–414.

An illustration is given [*] of Bell and Kirby's inclined trough washer which is an improvement on Bell and Ramsay's washer. The trough is pivoted near its upper end, so that the inclination can be varied. The inclination is increased when it is desired to rewash and finally discharge the accumulated shale.

W. S. Hutchinson [†] gives a graphic method of plotting sizing-tests in dressing minerals, and discusses the methods used by other investigators.

P. Schöndeling [‡] describes a dust-exhaust for preventing the formation of slimes in coal-washers. An appliance of this kind at the Mansfeld Colliery cost only £30 to install. It yields 10 tons of dust per hour.

Coal Handling and Storage.—F. M. Griswold [§] gives some notes on the storage of bituminous coal to obviate spontaneous combustion. Piles should not exceed 1500 tons, nor be more than 12 to 15 feet in thickness, and they should be at least 5 feet apart. The danger point is placed at 160° F.

Illustrations are given [‖] of the coal-handling plant at the New York Navy Yard.

An illustration is given [¶] of the new coal-shipping pier at Louisburg, Cape Breton.

Althans [**] describes the shipment of coal at the Gerhard Colliery at Louisenthal, on the Saar.

There is a description [††] given of a new coal-washing and conveying plant installed at the Stuart Street Power Station at Manchester. There are two conveyers of the gravity-bucket type.

Briquette Manufacture.—A description has been published of the new briquette plant at the Robert pit, near Wansleben. Special arrangements are made to obviate the formation of dust.[‡‡]

Illustrations are published [§§] of the coal-washing and screening plant

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[*] *Iron and Coal Trades Review*, vol. lxviii. p. 1057.

[†] *Transactions of the American Institute of Mining Engineers*, February 1904.

[‡] *Glückauf*, vol. xl. p. 1022.

[§] *Engineering and Mining Journal*, vol. lxxvii. p. 725.

[‖] *Engineering News*, vol. lii. pp. 68–70.

[¶] *Iron and Coal Trades Review*, vol. lxix. p. 627.

[**] *Glückauf*, vol. xl. pp. 1209–1214.

[††] *Engineer*, vol. xcviii. p. 354.

[‡‡] *Braunkohle*, 1904, pp. 225–227.

[§§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 249–251, with one plate.

of the Alstaden briquette works near Alstaden, in the Rhineland. The briquette plant is intended to be provided with two furnaces and six presses for a production per hour of thirty tons of briquettes, each weighing rather over 6·5 lbs. For the present, however, only one furnace and three presses have been erected. Pitch is used as a binding material for the anthracite. These are well mixed together, heated, the mass well kneaded, and pressed into briquettes.

P. Truchot [*] discusses cohesive materials suitable for combustible briquettes.

The influence of the tenacity of coal briquettes on their evaporative power has been investigated by E. J. Constam.[†] He shows that the evaporative power of similar coals is a function of their calorific value, and may be very accurately calculated from the results of calorimeter determinations.

H. H. Wotherspoon [‡] deals with recent advances in the utilisation of peat and lignite by briquetting them in Germany, and advocates their study in America.

R. Schorr [§] discusses binders for use in briquetting, and refers to the advantages of pitch and of magnesia cements.

A series of articles by J. Fulton [||] on the fuel briquetting industry has been published. The author deals with the materials of which bricks are made, the binders, the fuel value, the shapes of briquettes, and describes the processes and machinery used.

Experiments on the utilisation of peat are described by L. C. Wolff.[¶]

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[*] *La Revue de Chimie industrielle*, vol. xv. No. 175.

[†] *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 973–975.

[‡] Paper read before the New York Academy of Sciences, March 1904; *Engineering and Mining Journal*, vol. lxxvii. p. 562.

[§] *Transactions of the American Institute of Mining Engineers*, February 1904.

[||] *Mines and Minerals*, vol. xxv. pp. 106–109.

[¶] *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 887–892.

PRODUCTION OF PIG IRON.

CONTENTS.

I.—*BLAST-FURNACE PRACTICE.*

Theory of the Blast-Furnace.—The theory of the blast-furnace process is discussed by R. Schenk.*

Blast-Furnace Construction.—In the construction of the blast-furnace, adopted by F. Burgers at Duisburg, and elsewhere in Germany, the lower part of the furnace is built of iron plates, flanged and bolted together externally, and ribbed internally, the spaces between the ribs being filled with brickwork. About 15 gallons of water per minute are run on to each 100 square foot of the shell, which is provided with water rings or troughs at intervals. At Bruckhausen, one furnace has been making 500 tons daily, with a consumption of 20 cwt. of coke per ton. †

F. Burgers ‡ describes a new form of blast-furnace construction. It consists of brickwork to the top of the boshes only, and beyond this, of a water-cooled iron stack. Sections are shown illustrating this form of construction as put into practice at two blast-furnaces, at Bruckhausen and Gelsenkirchen. The cast-iron segments forming the shaft have a thin inner lining of firebricks. A similar furnace has been in successful use for the past five years at the Vulkan works near Duisburg-Hochfeld, and another has been in opera-

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* *Zeitschrift für Electrochemie*, vol. x. p. 397.

† *Iron Age*, June 9, 1904, p. 27.

‡ *Stahl und Eisen*, vol. xxiv. pp. 401–402.

tion since February at Bruckhausen on the Rhine. Three blast-furnaces of this construction are to be erected at another German works. The Bruckhausen furnace works exceedingly well, and makes about 500 tons of basic pig daily, at the same fuel consumption as the ordinary form of furnace, namely, about 1 ton of coke per ton of pig.*

No. 3 furnace at the works of the Carnegie Steel Company at Youngstown, Ohio, is being reduced in height from 106½ feet to 90 feet by cutting out about 16 feet of the stack below the top, without interfering with the charging mechanism. Part of the skip hoist has been removed during the operation. A photograph has been published.†

Illustrations are given ‡ of the Pollock bosh cooling plates in which the water is not under pressure.

Charging Arrangements.—Illustrations are given § of a machine for loading barrows from the stock piles at blast-furnace. It consists of a portable elevator with an inclined endless belt in one plane. It is driven by an electromotor which also serves to move the machine as well as to work the belt.

F. C. Roberts || describes a blast-furnace charging and distributing apparatus designed to give a proper distribution of the volume of the materials and a proper admixture of the fine and coarse materials. The skips are emptied into angularly adjustable shoots from which the charge falls through a small bell and hopper into the lower and larger bell and hopper.

An illustration is given ¶ of the furnace top and hoist of La Belle furnace at Steubenville, Ohio.

C. Schiebeler ** describes the way in which electric power is used in connection with blast-furnace hoists.

D. Baker †† draws attention to the delays, expenses, and general irregularities of furnace working inseparable from the hand charging ordinarily in vogue, and from that carried out by mechanical devices generally. The nearest approach to careful hand filling is in the use of the top invented by A. E. Brown some years ago, by which each skip load is directed into a different position of the hopper.

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* *Stahl und Eisen*, vol. xxiv. p. 402.

† *Iron Trade Review*, April 14, 1904, p. 34.

‡ *Ibid.*, July 21, 1904, pp. 48–49; *Iron and Coal Trades Review*, vol. lxix. p. 412.

§ *Iron Trade Review*, April 21, 1904, pp. 62–63.

|| *Iron Age*, June 23, 1904, pp. 18–20.

¶ *Engineering News*, vol. li. p. 437.

** *Stahl und Eisen*, vol. xxiv. pp. 452–456, with five illustrations.

†† *Iron and Coal Trades Review*, vol. lxix. p. 1198–1199.

Charcoal Blast-Furnaces.—Peat charcoal is used at Neuhütte near Schmalkalden for pig-iron production. Good dense peat charcoal in lumps as large as possible is, according to J. W. Bleymüller,* equal to good charcoal and is not dearer. Its use in blast-furnace practice presents no difficulties if it is not too rich in ash, if the ore is not too small and dusty, if the furnace is not more than 40 feet high, and if after each tapping the bosh is cleared of dust produced by the compression of the fuel. At Neuhütte the addition of peat charcoal does not exceed 25 to 33 per cent. of the fuel charged. The peat charcoal should contain little sulphur and phosphorus. The pig iron at Neuhütte contains:—

	Per Cent.
Iron	91·273
Carbon	2·436
Silicon	1·069
Manganese	5·016
Sulphur	0·073
Phosphorus	0·111
Copper	0·022
Chromium	0·000
Titanium	0·000

The iron ore used consists of spathic iron ore altered into limonite, with 40 to 50 per cent. of iron and 4·5 to 8·5 per cent. of manganese. The ore is rich in lime. The flux consists of 8 per cent. of ferruginous limestone and some fluorspar.

J. Bicheroux † describes the methods employed for the production of charcoal pig iron in the Ural district. The works, which are of a primitive type, usually consist of one or two furnaces of 40 to 50 feet high, each furnace being provided with 3 tuyeres, through which a feeble blast is projected. The ores are obtained from open workings not far from the furnaces, and are calcined by means of wood fires. They contain from 56 to 63 per cent. of iron. The production at these furnaces seldom reaches more than 12 or 15 tons per diem, and the labour necessary is enormous. Sometimes larger furnaces are met with, rising to 60 or 70 feet, and having 4 tuyeres. The blast is heated to 350° or 400° C. in Calder stoves, or to 600° or 700° in Cowper stoves. The charcoal preferred is that from birch or pine; oak is but little valued, and aspen charcoal is too friable. The wood is carbonised in kilns, and hardly ever in stacks. The kilns hold from 400 to 1000 cubic yards of wood, and one workman can super-

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* *Bihang till Jernkontorets Annaler*, 1904, pp. 167–170.

† *Revue Universelle des Mines*, vol. v. pp. 167–175.

intend four kilns. Carbonising a charge occupies, in the larger kilns, about five days, cooling seven, and drawing and re-charging occupy about four days. The yield of charcoal from these kilns is nearly double that of the burning conducted in heaps. The cost of production is somewhat high, the finished fuel costing about 22s. per metric ton. The cost of ore varies according to the distances from which it has to be procured, and is lowest in winter and highest in the rainy season. It may be estimated at 7s. to 7s. 6d. per ton at works. Limestone, &c., costs slightly over 2s. per ton of pig iron, which allowing for all charges, costs about 48s. per ton.

Some details have appeared * of the Pioneer charcoal furnace and plant at Cleveland, Ohio. The furnace is 70 feet in height with a 12-foot bosh and has a capacity of 130 tons daily. Blast is heated to 1250° F. in three Cowper-Roberts stoves, each 16 by 70 feet.

Purifying Boiler Feed Water.—C. Svensson † describes a method of purifying boiler feed water adopted at an ironworks in Pittsburg.

Hot-Blast Stoves.—J. L. Stevenson ‡ shows a pyrometer attachment for hot-blast stoves to actuate a throttle-valve on the cold air supply pipe, and thereby automatically regulate the temperature of the blast.

Illustrations are given § of the larger and smaller forms of the Morrison-Kennedy chimney sliding valve for hot-blast stoves.

Sections are given ‖ of the hot-blast stove designed by A. P. Gaines, with a separate combustion chamber so that all the space in the stove itself may be used for heating purposes.

Blowing-Engines.—In an exhaustive paper on recent improvements in blowing-engines O. E. Westin ¶ describes a simple and efficacious blast-valve devised by E. Bertrand at Kladno. The Riedler blowing-engine frequently required attention, and as an experiment Bertrand used for the valve a thin 1 to 2 millimetre thick round steel plate which has given excellent results.

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* *Iron Age*, June 23, 1904, pp. 26–28.

† *Bihang till Jernkontorets Annaler*, 1904, pp. 229–234.

‡ *Iron and Coal Trades Review*, vol. lxix. p. 102.

§ *Iron Trade Review*, July 7, 1904, pp. 92–94.

‖ *Ibid.*, June 2, 1904, pp. 77–78.

¶ *Bihang till Jernkontorets Annaler*, 1904, pp. 87–122.

Illustrations are given * of various types of horizontal and vertical blowing-engines built by the Mesta Machine Company.

An illustration and a number of sections are given † of the blowing-engine at the Adrian furnace near Du Bois, Pennsylvania.

Blast-Furnace Gases.—The Zschocke apparatus for purifying and cooling blast-furnace gas consists of a vertical tower across which a series of triangular wooden slats are placed. Water is sprayed down through them.‡

E. Butler § gives further illustrations of large-sized gas-engines.

Illustrations are given ‖ of Theisen's centrifugal gas-washer.

Cyanogen in the Blast-Furnace.—According to C. Bolin,¶ the Ostrau coke used at the Donawitz blast-furnaces contains 0·14 per cent. of potash and 0·25 per cent. of soda, or altogether 0·39 per cent. of alkali. In view of the fact that one part of potash represents about 0·55 part of cyanogen and that one part of soda represents about 0·84 part of cyanogen, Braune's view is not borne out that the formation of cyanogen must be at least as great in the coke-oven as in the blast-furnace. That cyanides are abundantly formed in the blast-furnace can be observed at the new Eisenerz furnaces where a thinly fluid material collects at the tuyeres. This material was grey at Eisenerz (I.) and black at Donawitz (II.), and contained—

	I.	II.
Carbon	0·45	5·17
Insoluble	1·76	12·19
Potassium	45·83	41·34
Sodium	5·85	4·45
Cyanogen	14·62	10·61
OCN	5·12	1·09
Chlorine	1·56	1·35
Carbonic anhydride	16·31	17·21
Water	3·42	...

Assuming that the radicles CN, OCN, and Cl are combined with potassium, and that the remaining potassium and all the sodium exists as carbonate, the following composition is obtained :—

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* *Iron Trade Review*, August 11, 1904, pp. 36–38.

† *Ibid.*, May 5, 1904, pp. 100–102.

‡ *Iron Age*, July 14, 1904, p. 16.

§ *Page's Magazine*, vol. iv. pp. 508–511.

‖ *Engineering*, vol. lxxviii. pp. 76, 78–79.

¶ *Teknisk Tidskrift. Kemi och Bergsvetenskap*, vol. xxxiv. pp. 24–26.

Insoluble in water	2·21	17·36
KCN	36·55	26·52
$KOCN$	9·67	2·09
KCl	3·28	2·83
K_2CO_3	30·83	40·59
Na_2CO_3	13·45	10·72
H_2O	3·42	...

The calculated proportions of carbonic anhydride (15·42 and 17·39 per cent.) agrees satisfactorily with those determined. The greater part of the cyanogen compound dissociates higher up in the furnace and aids the ore reduction. A portion passes away unaltered with the gases and is deposited in the flues. Cyanogen in small quantities was found in flue-dust by Ledebur. It may however occur in considerable quantities, as the Austrian Alpine Company found to its cost. In the summer of 1901 about 20 tons of flue-dust from the Hieflau charcoal blast-furnace in Styria was tipped into the river Ems; and an enormous quantity of fishes were killed. Cyanogen was found in the dust, and £2850 damages had to be paid.

Dust Explosions at Blast-Furnaces.—E. A. Uehling* advocates the use of dust-catchers or other means for removing dust from blast-furnace gas, which is thereby greatly improved for heating purposes. The use of explosion doors in the blast-furnace top is condemned as conducive to explosions by the leakage of air; a tight top is to be preferred. Much of the trouble from dust is due to fast driving, high blast pressure, and excessive furnace height. For Mesabi ore a height of 60 feet should be sufficient. The present tendency is towards an increased batter above the boshes.

By-Products.—According to the fortieth annual report† on alkali, &c., works, there was an increase in the production of sulphate of ammonia from blast-furnaces in Scotland during 1903, where all the furnaces, except some at the Carron works, are equipped with by-product plant. During 1903 the average furnaces in blast were 85·73, as compared with 84·35 in 1902, and the average production of iron in those years was 289 and 295 tons respectively.

English Blast-Furnaces.—At T. Butlin & Co.'s works,‡ near Wellingborough, tunnel lining segments, weighing 3 to 5 cwt. each,

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* *Iron Age*, April 7, 1904, pp. 10–11.

† *Fortieth Annual Report on Alkali, &c., Works*, June 17, 1904, p. 180 (price 9d.).

‡ *Engineer*, vol. xcviii. p. 5; *Engineering*, vol. lxxvii. p. 856; *Engineering Review*, vol. xi. pp. 212-216, with four illustrations.

are cast at the rate of 100 tons weekly direct from the blast-furnace in ordinary sand moulds. The works contain four blast-furnaces, 50 feet high, with 15-foot boshes. Blast is heated to 450° or 500° C. in iron pipe stoves. Northamptonshire oolitic ore, containing 38 per cent. of iron, is melted with about 15 per cent. of limestone as flux. About 22½ cwt. of fuel is used per ton of iron, and 30 cwt. of slag is made. The foundry iron has the following composition:—

Graphite.	Si.	S.	P.	Mn.
2·85	1·92	0·10	1·19	0·24

The slag contains:—

SiO_2.	Al_2O_3.	CaO.
32 to 33	15	40 to 43

It is cast into rectangular blocks of 13 cwt., which are broken up for road metal. The iron is run into ladles, holding 3½ to 5 tons, which are taken to the foundry, where the metal is transferred to casting ladles. The segments for lining tunnels are cast in sand moulds. After stripping and cooling, their flanges are faced by a milling-machine, built specially for the purpose, and then they are coated with Angus Smith's composition.

French Blast-Furnaces.—It is reported that the No. 5 blast-furnace at the Longwy steelworks,* which was blown out on July 5, had been in operation since January 1884. It has thus been at work for 20 years, 6 months, and 5 days, during which period it produced 483,531 tons of pig iron. This is a record life for a French blast-furnace.

German Blast-Furnaces.—H. Wedding † describes the Thale ironworks.

The Deutscher-Kaiser ironworks state that the consumption of coke in the Burgers iron shell blast-furnaces erected there is not greater than that in the ordinary type of blast-furnace at the same works. This is about a ton of coke per ton of basic pig iron made. The cooling water needed by the shell furnace is 2·5 to 3 cubic metres per minute, its temperature being raised from 15° to about 35° C. It is anticipated that this consumption of water will be considerably reduced. The appearance of the furnace generally creates much satis-

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* *Echo des Mines*, vol. xxxi. p. 1060.

† *Verhandlungen des Vereins zur Beförderung des Gewerbfleisses*, 1904, pp. 199–224, with three plates.

faction. A furnace of this kind is being erected by the Dortmund Union works.*

B. Osann † observes that the Gutehoffnungshütte at Oberhausen was founded in 1781. It has been under the present firm since 1873. The earlier history is referred to, followed by a description of the works and its recent history. The Bessemer process was introduced in 1872. In 1878 the basic Bessemer process was also introduced, and both processes were simultaneously carried on for a time, the acid process being afterwards abandoned. In 1878–1879 the open-hearth process was put into operation, and in 1894 the present basic Bessemer plant was erected. In 1872–1873 this works paid in salaries and wages £437,000, but in 1899–1900 this amount had increased to £923,000. The blast-furnaces are described and illustrated. Furnace No. 6 has a capacity of about 12,700 cubic feet, and is blown with 7 tuyeres, using blast at 750° C., and at a pressure of 430 to 450 grammes per square centimetre. The ratio of total height to maximum width is rather over 3 : 1. Cowper stoves are employed. The charge takes about 10 to 11 hours to pass through the furnace when basic Bessemer iron is being made, about 180 tons of pig iron being made daily. When hæmatite iron is being made the daily output is about 160 tons. In the latter case the ore mixture yields about 50 per cent. of iron, and in the former 48. The temperature at the throat is 180° when basic iron is being made; from 210° to 220° for hæmatite iron, and from 300° to 400° in the case of ferro-manganese. The gas contains about:—

CO_2.	CO.	N.	H.	CH_4.
5·0	29·0	63·0	2·5	0·5

with about 7 per cent. of water vapour. The gas is first passed through dry dust-collectors, which reduce the dust to about 5 grammes per cubic metre, and is then passed through washers provided with Körting spray jets. These reduce the dust to about 3 grammes per cubic metre, and the temperature of the gas from about 120° to 40° or 50°, the cooling water being increased in temperature at the same time from 9° to 30°. The gases next pass in a long zigzag passage through a coke scrubber, and when they leave this the dust only amounts to about 0·478 gramme per cubic metre, farther reduced in the passage to the gas-motors to 0·25 gramme. It was found, however, that even this was too high, as the motor required

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* *Stahl und Eisen*, vol. xxiv. p. 475.

† *Ibid.*, pp. 437–446, 501–507, with three plates and illustrations in the text.

to be frequently cleaned. Fans were therefore introduced instead of the coke scrubber, and a fan requiring 0·08 horse-power, and using 3 to 4 litres of water per cubic metre of clean gas, further reduced the dust to only 0·025 gramme per cubic metre. The water required cannot, it is found, be further reduced. If this is attempted the amount of dust immediately increases. On the other hand, it is hoped that the necessary power may be somewhat lowered.

The ferro-manganese produced at the works contains:—

Mn.	C.	Si.	P.
60 to 80	6 to 7	0·2 to 0·3	0·18 to 0·37

The basic pig iron, as tapped from the blast-furnace, contains about:—

C.	Mn.	Si.	P.	S.	Cu.
3·0	1·5	0·5	2·2	under 0·17	0·08

Passing to a mixer, the metal leaving this for the steel plant contains:—

C.	Mn.	Si.	P.	Cu.
3·0	1·0	0·35–0·45	2·2	0·08

and, at the most, 0·07 to 0·08 per cent. of sulphur, the percentage usually being from 0·06 to 0·07. It takes about 10 minutes to convey the iron from the blast-furnace to the mixer-house, and the shaking that it undergoes during this passage helps considerably towards desulphurisation. Indeed, it is thought that about 50 per cent. of the sulphur eliminated is got rid of during transit. The mixer holds 120 tons, and the converters each hold 15 tons of metal. Analyses are given showing how this sulphur is eliminated in transit:—

	Manganese. Per Cent.	Sulphur. Per Cent.
Iron at the blast-furnace	1·16	0·19
Iron on reaching mixer	0·83	0·11
Iron on reaching converter	0·78	0·06

The converter bottoms last for 40 blows, and the rest of the lining for 220. The lime added to the converter charge amounts to 18 per cent. About 1 per cent. of ferro-manganese is subsequently added to the metal in addition to spiegeleisen. The converter slag amounts to about 25 per cent. of the pig iron charged, and contains:—

SiO_2.	Al_2O_3.	CaO.	MgO.	MnO.	FeO.	Fe_2O_3.	P_2O_5.
6·72	1·70	44·92	3·64	5·28	12·28	5·84	18·88

together with 0·32 per cent. of sulphur. Of late the phosphoric anhydride averaged from 15 to 17 per cent., 80 per cent. being soluble in citrate solution.

The old open-hearth plant comprises four 12-ton furnaces, while the new plant has two of 25-tons capacity, a third, of 25 tons, being in course of erection. The gas main is very large in the case of the new plant. Steam is used in the producers, and air is supplied by aid of a fan. The gas produced contains:—

Carbon Monoxide.	Carbon Dioxide.	Hydrogen.	Nitrogen.
23 to 24	5 to 6	11 to 12	50

The furnaces are basic lined, dolomite being used, with magnesite bricks as a separating layer, and a silica roof. Ordinary clap valves are employed, with Fischer valves in the new 25-ton furnaces. The old furnaces make about 72 tons in the 24 hours, the new ones 120 tons each, in 6 charges, this large output being only possible with a mixture of 75 per cent. of a pure scrap, and 25 of hæmatite pig iron containing only 0·07 per cent. of phosphorus. Using best Westphalian gas coal, the fuel amounts to from 25 to 27 per cent. About 1 per cent. of ferro-manganese is used for the recarburisation, together with ferro-silicon and spiegeleisen. The loss amounts to about 6 to 6·5 per cent. Material for boiler and ship-plates, axles, tires, &c., is produced, the slag made containing, in the one instance given:—

SiO_2.	Al_2O_3.	CaO.	MgO.	FeO.	Fe_2O_3.	MnO.
24·74	3·99	31·33	12·80	7·78	0·61	15·06

together with 1·12 per cent. of phosphoric anhydride, and 2·73 of calcium sulphide.

The pig iron used contained from 2 to 3 per cent. of silicon, and at the most 0·1 of phosphorus, together with 0·02 of sulphur, and from 1·0 to 1·2 per cent. of manganese.

The rolling-mills are dealt with, and also the foundry. The drying methods in use at the Sterkrade foundry are specially described. A plan of the foundry is given. Steel castings are made here by the aid of one 45-ton open-hearth, two of 25-tons maximum capacity, and one of 10 tons, about 15,000 tons being made annually.

Russian Blast-Furnaces.—A description has been published* of the ironworks in the vicinity of Libau, the centre of the South Baltic metal industry.

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* *Montan Zeitung*, vol. xl. p. 339.

American Blast-Furnaces.—R. Kunz[*] observes that the time appears now to have passed when every new blast-furnace in the United States seemed to be erected with a view to a still larger output than the last. As is well known, it has been attempted to erect blast-furnaces with the daily outturn of 500 or possibly 600 tons, and occasionally 800 to 1000 tons was stated as the proposed daily production. As a matter of fact, however, only one furnace has made 1,000,000 tons of pig iron with a daily average production of 500 tons in one campaign, this being furnace D of the Edgar Thomson Steelworks. Many furnaces have made larger daily returns for short periods, or more than 1,000,000 tons in one campaign, but they have not attained this average daily yield. Furnace D, too, probably holds the record for the production in any one day, having made 841 tons. This refers to a period when ore averaging nearly 60 per cent. of iron was being dealt with. It is therefore no better in reality than the results obtained at a furnace at Bruckhausen where, with a yield of 39 per cent. from the ore, an output of 580 tons of pig iron in twenty-four hours has been attained.

These very large blast-furnaces appear to be no longer being erected in the United States, the standard size being equal to a daily output of about 400 or 450 tons. This may be due to the ores now being smelted being of lower grade. The author describes such a plant with two blast-furnaces placed 100 yards apart, with a stack midway, and four stoves between each furnace and the stack. Each furnace has a dust-catcher at its side. In front lie the bins for ore, limestone, and coke, and lines of rail are available for carrying away the iron and slag, the furnaces and stoves being placed on a level high enough to allow the iron and slag being conveyed away in this manner. The gas leaving the dust-catcher passes direct to the stoves and boilers.

The 100-foot furnaces are now being abandoned in favour of those of 85 to 90 feet in height, but of this height 10 to 15 feet must be deducted for the movement of the bell and the necessary charging space. On the other hand, while the furnaces are being made lower, the width at the boshes is being increased as much as possible. This width now reaches 21 to 24 feet, the angle at the boshes being somewhat less than 75°. Other details as to shape are given. The slag tap-hole is placed about 3 feet below the tuyeres. The way the

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[*] *Stahl und Eisen*, vol. xxiv. pp. 624–629, with eight illustrations.

furnace is erected is described. The gases are taken off by two to four pipes at the sides, while explosion doors are also provided. The escaping gases are led into a main which passes into the dust-catcher, the gases passing, without any further treatment, to the stoves and boilers. The yield of iron is higher than is customary in Germany, and the flue-dust has a higher specific gravity, and settles more readily than the lighter dust of the German works. The American contention that they have to deal with too much dust in their furnace gases to enable them to employ gas-engines is not a true statement of the case. The furnace linings last from five to six years. Bricks of small size are alone employed.

After giving other details relating to the construction of the blast-furnace the author proceeds to a consideration of the hot-blast stoves that are in use. These are of very variable form. The most usual is perhaps a two-way brick stove with an elliptical combustion shaft at the side. The goose-neck valve is used for the gas inlet, two similar valves serving to take away the burnt gas. The mushroom valve is used for the hot-blast. The stack is of sheet iron with a thin lining. The boilers are usually of the vertical type, fired with blast-furnace gas, but provided with an arrangement which enables them to use coal if necessary. Large gas-engines to utilise the excess of blast-furnace gas are but little used, though some of considerable size have been erected. The blowing-engines are nearly all vertical. These are usually of certain standard types. Five engines are employed for two furnaces—two for each furnace, and one in reserve. Each furnace is blown separately. The Kennedy valve is very commonly employed. A speed of more than forty revolutions a minute is rarely exceeded. A number of further details are also given. Despite the high rate of wages, complete reliance on machinery in connection with the ore-yards, &c., is no longer customary. There is the danger that frost or accident may suddenly bring about a cessation of work where machines alone are employed without hand labour. Pig beds are no longer used, the iron going straight to the mixer or to the casting machines, which are of varying type. Four men are employed for each furnace. It was formerly also customary to have one man at the top, but this is no longer done, automatic methods operated from below being employed instead. A man is employed at the stoves, whose help is also available in connection with the furnaces. His duties include, in addition, the supervision of the tuyeres and the testing of the samples. The blast has usually a temperature of 800° F., which when needed may be raised to 1100° F. This is for an iron with from 1·25 to 2·0 per cent. of silicon and as little sulphur as possible, usually between 0·03 and 0·04 per cent. For special iron the blast temperature is higher, and the coke charge is also proportionately increased. For iron of the composition given above, it has been reduced to 0·825 ton of coke per ton, but it usually exceeds this figure. The Uehling-Steinbart pyrometer is in frequent use for temperature measurements. The blast used has a pressure of 15 to 17 pounds, but with irregular working may rise to 24 pounds. High pressures of blast are rendered necessary when small-sized ore is being used. The furnaces are tapped at four-hour intervals, and slag every ninety minutes after closing the tap-hole. The slag is seldom granulated. The railways charge for the removal of granulated slag, but remove ordinary slag free, as it is used as ballast. The iron tap-hole is nearly freed by means of an air-drill, and finally opened by hand. One tap may fill seven ladles, which are emptied automatically into the mixer or casting-machine. The iron runs from the furnace to the ladle through cast-iron channels. Immediately after tapping, while the channels are still hot, any iron adhering is removed and the channel slushed with lime water. They dry thoroughly before the next tap, and any boil is consequently avoided. Fine ore has to be used to a greater and greater extent each year. This leads to the furnaces hanging with some frequency. The disadvantages accruing from the use of fine ore are partly neutralised by the coke employed being hard. It is largely made in beehive ovens, in which it is cooled down by steam. This leads to considerable loss, as the resulting gas is not in any way utilised. More modern types of coke-oven, arranged for the collection of the by-products, are coming gradually into use, but the coke made is said to be less strong. The quantity of flue-dust produced is considerable. This is charged back as such into the furnace. The men employed are largely Slavs who only speak broken English. In the Southern States coloured labour is employed.

Illustrations are given * of the blast-furnace plant of the Zenith Furnace Company at Duluth.

A plan is given of the works of the Lookout Mountain Iron Company at Battelle, Alabama, where ore, coking coal, and limestone are found closely adjacent. The furnace is 85 feet in height with 19½-foot boshes and a 12-foot crucible. A short description of the plant is given.†

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* *Iron Trade Review*, August 11, 1904, pp. 40–42.

† *Ibid.*, August 4, 1904, pp. 68–71; *Iron Age*, August 4, 1904, pp. 27–29.

A plan and illustrations are given* of the Adrian Furnace at Falls Creek near Du Bois, Pennsylvania. The furnace is 80 feet in height, 19½ feet at the boshes, 12 feet in the hearth, 13 feet at the stockline, and the bell is 9 feet in diameter. It has a Julian Kennedy top without explosion doors, and it is blown through twelve 5-inch tuyeres.

Japanese Blast-Furnaces.—C. E. Heurteau † describes the establishment and development of the Imperial Ironworks of Wakamatsu, in the island of Kiushiu, in Japan. These works were founded in 1875, and the blast-furnaces commenced operations in 1882, but in 1890 further developments took place under the auspices of the Gutehoffnungshütte, the Imperial Government having failed to grant the necessary credits. At present the work consists of the following departments—three coal mines about 27 miles distant, yielding a rich coal, but an indifferent coke with a heavy ash. To improve the latter, the coal is mixed, before coking, with an anthracite from the Island of Amakusa. There are eighty beehive ovens, each coking four tons of coal per forty-eight hours; but these ovens are to be replaced by Coppée ovens, of which 200 are to be built, each capable of dealing with six tons of coal per forty-eight hours. There are two blast-furnaces, the waste heat from which fires a battery of twenty-eight boilers. The furnaces are about 74 feet in height, with a production of 165 tons per twenty-four hours. Each furnace is furnished with four Cowper stoves, 98 feet high and 19 feet in diameter, the blast being heated to 700°, and driven through eight tuyeres at a pressure of 45 centimetres of mercury, the power being supplied by four blowing-engines of 800 horse-power each. Twenty-four Lancashire boilers have been erected and twenty-eight more are contemplated. The burden consists of 1 ton of Chinese ore, and about 6 cwts. of Japanese ore per ton of pig made, the corresponding coke charge being 22 cwt. and 6 to 7 cwt. of limestone. The total cost of materials is £3, 2s., viz. 24s. 10d. for ore, 28s. for coke, and 2s. 10d. for limestone, the cost of wages and upkeep being 6s. 4d. This cost could, however, be reduced to about £2, 16s., while imported pig iron costs about £3, 10s. in Japan, with a customs duty of 3s. per ton. The composition of the pig iron was:—

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* *Iron Trade Review*, May 5, 1904, pp. 99–102.

† *Annales des Mines*, vol. vi. pp. 102–117.

	Per Cent.
Carbon	3·50
Silicon	2·00
Manganese	1·50 to 2·00
Phosphorus	0·06
Sulphur	0·03 to 0·06

As the stocks of pig iron are sufficient for the needs of the steelworks, there is only one furnace now working.

History of Iron.—An account of the early history of iron is given by O. Vogel,* showing that in all probability the oldest metal in use was iron, and that meteoric iron was the first to be used. In support of these views, he gives several quotations for the Finnish epic poem "Kalewala."

An illustration is given † of an old tilt hammer which is still in use at Midsomer in Somersetshire.

H. G. Heymann ‡ traces the history of the Saxon iron industry. The history of the iron industry of Saxony is also traced by Schiffner.§ Small quantities of iron were made in Saxony in the very earliest times, deposits of iron oxides outcropping in many places in the upper Erzgebirge—"ore mountains." The rise of silver-mining with the concomitant necessity of iron tools caused the iron industry to be developed. Records show that a foundry was erected at the Pirnai works in 1572, and experiments were made there in 1574 in connection with the manufacture of steel. The increase in the number of forges soon led to a scarcity of wood, and laws relating to this had to be introduced and enforced. In addition to bar iron, wire and sheets were made, and tin plate began to be manufactured in 1620 at forges adjacent to the tin ore deposits. Yarranton studied this industry on the spot in 1665, and subsequently introduced it into Cornwall. In 1780, 40 ironworks were in operation, and hot-blast was introduced at the Morgenrothe works in 1830. In 1850 there were at 23 ironworks 17 blast-furnaces in operation, 9 of which were operated with hot-blast. The author sketches the rise of the industry from 1830 onwards and gives some statistics as to the larger existing Saxon works.

H. von Wichdorff ‖ describes some ancient mines and ironworks in Pomerania.

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* *Bericht über den Allgemeinen Bergmannstag*, 1904, pp. 305–334.

† *Engineering*, vol. lxxvii. p. 761.

‡ *Montan Zeitung*, vol. xl. pp. 337–338.

§ *Stahl und Eisen*, vol. xxiv. pp. 609–610.

‖ *Zeitschrift für Ethnologie*, vol. xxxvi. No. 1.

A history of the iron industry of the province of Örebro, Sweden, has been published.*

The blast-furnace ordinance of Queen Christina of November 6, 1638, has been reprinted by H. Braune,† who traces the development of the Swedish blast-furnace from 1425 to the present time.

A history of the Royal Ironworks at Malapane has been written by Gentzen ‡ on the occasion of the 150th anniversary of its foundation.

H. Wedding § deals historically with the Malapane ironworks in Upper Silesia. In 1740 bog iron ore began to be mined again after the cessation of operations during the Seven Years' War in Lower and Upper Silesia, and the brown iron ores of Triassic age were mined at Tarnowitz. Clay ironstone was also mined in a few places. Fifty-six ironworks then existed in Silesia, but they were almost all bloomeries, and there were only a few scattered blast-furnace plants which the author names. Frederick the Great undertook the rehabilitation of the mining and metallurgical industries. At the close of the second Silesian war there were no cannon of any size left nor projectiles. The king therefore caused ironworks to be erected on the Malapane River with blast-furnaces and fineries.

E. Baur ‖ gives some interesting historical data dealing with the utilisation of the waste gases from blast-furnaces, especially as regards the early suggestions of Faber du Faur. The data are culled from the records of the Wasseralfingen works and the Royal mining records at Stuttgart. The sketches given are reproductions of those found in the records, some of which had been made by Faber du Faur himself. In 1832 the latter utilised these gases for the first time in a hot-blast stove. Two years before this Neilson had discovered the advantages of hot-blast. In 1831 experiments were made in South Germany in this connection, not, as Neilson did, by the aid of coal, but by endeavouring to utilise the heat from the blast-furnace itself. They were not a success. They were, however, investigated and reported on by Faber du Faur, who suggested the use of the waste furnace gases as the source of heat. Sketches are given of the first stove

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* *Blad för bergshandterings Vänner*, 1903, p. 210; *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 197–199.

† *Jernkontorets Annaler*, vol. lix. pp. 1–114; with twelve folding plates.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. lii. pp. 201–231.

§ *Stahl und Eisen*, vol. xxiv. pp. 756–761.

‖ *Ibid.*, vol. xxiv. pp. 562–567, with nine illustrations.

so erected. This consisted of horizontal iron pipes in a brick chamber, erected at the Wasseralfingen works. The way the gas was withdrawn from the blast-furnace is shown, and other methods of utilisation suggested by the same inventor are described and illustrated. Faber du Faur was born at Stuttgart in 1786 and died there in 1855.

A report of the meeting held to commemorate the fiftieth anniversary of the Thomas iron company has been published.* The meeting was held on June 1. In connection with the history of the company, which was distributed at the time of the celebration, the pamphlet constitutes a valuable record of the life of a company which was in many ways a pioneer in the iron manufacture in the United States.

In connection with the judgment of the Court of Appeal at Rome on May 21, 1904, in favour of the Ferro-Nickel Company in the lawsuit against the Terni Steelworks, a case that has lasted fourteen years, a history of nickel steel has been published.†

A souvenir medal commemorative of the establishment of the nickel industry by Joseph Wharton has been coined by the International Nickel Company, of New York. It is made, as would naturally be inferred, of refined nickel, and is a beautiful specimen of the coiner's art. The obverse presents a portrait of Joseph Wharton, with this inscription: "Malleable nickel first produced in 1865 by Joseph Wharton, Sc.D., LL.D." The reverse carries the legend: "American Malleable Nickel. International Nickel Company, 1904. St. Louis Exposition." The medal commemorates an important event in industrial history.

Recent progress in the iron industry is described by B. Neumann.‡

E. Treptow § gives an account of mining and metallurgy in Japan in the year 1850. The oldest iron manufacture was in the year 1264 at Sugaya from magnetic sands.

Portraits have been published ‖ of H. M. Howe, R. A. Hadfield, C. B. Dudley, J. Gayley, A. Ledebur, A. Carnegie, H. H. Campbell, H. von Jüptner, J. A. Brinell, Maunsel White, and B. H. Brough.

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* The Thomas Iron Company. *Proceedings* of the Special Meeting to Celebrate the Fifteenth Anniversary of the Formation of the Company. Hokendauqua, Pa. Published by the Company. Pages 64; illustrated.

† *Echo des Mines*, vol. xxxi. pp. 936–939.

‡ *Chemische Zeitschrift*, vol. iii. pp. 754–757.

§ *Der Altjapanische Bergbau und Hüttenbetrieb.* Freiberg, 1904.

‖ *Iron and Steel Metallurgist*, vol. vii. pp. 92, 209, 259, 349, 470, 565; *Iron and Steel Magazine*, vol. viii. pp. 1, 205, 301, 397, 493.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

Foundry Iron.—J. E. Johnson * gives some notes and observations on cast iron, and compares cupola-melted metal with metal direct from the blast-furnace for making castings in respect of its composition and behaviour. The relation between kish and silicon and other elements is discussed, and much information is given on the behaviour of the kish and of the effect of the graphite in the iron on the castings. The effect of sulphur also receives much attention.

O. Leyde † points out that as a rule blast-furnace plants making foundry iron have to provide rather for the needs of foundries making thin castings rather than for those which also make castings with greater thickness of metal. There is therefore a tendency to make a rather highly priced high No. 1 silicon iron than a lower silicon iron that is less used. This often leads to difficulties in mixing. Every varying thickness for a casting corresponds theoretically, as the author shows, with a definite percentage of silicon, and the author deals with the practical application of this. There is in practice a definite limit for the silicon contents of a grey pig iron. It must not contain less than 0·8 per cent. nor more than 3 per cent. If it exceeds 3 per cent., then in thin castings the metal is apt to be overhard, and to have a bright glossy fracture. If there is less than 0·8 per cent., even the thickest castings are too hard, and apt to be quite white and brittle, and incapable of being manipulated in the ordinary way. When this iron is melted down there is a loss of silicon, and a certain degree of regularity is observable in this loss. Long series of analyses have shown the author that it varies on the average from 0·45 per cent. in high silicon mixtures to 0·03 per cent. in the case of those low in silicon. It was very evident in these analyses how much more irregular was the working in narrow cupolas than in those of larger diameter. The foundry man is at a loss when calculating his charge in that, as a general rule, the metals he has to select from have not been sold under definite guaranteed analysis, though this is the rule with many of the larger works. The author does not think that there is any need for any such definite numbering of the various varieties of pig iron as was suggested by the Cast Iron Session of Testing Engineers held at Philadelphia in June 1903. These recommended that

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* *Transactions of the American Institute of Mining Engineers*, February 1904.

† *Stahl und Eisen*, vol. xxiv. pp. 879–883.

foundry irons should have the following composition, a 10 per cent. difference either in the case of the silicon being permissible, and of 0·1 per cent. in the case of the sulphur:—

No.	Silicon.	Sulphur.
	Per Cent.	Per Cent.
I.	2·75	0·035
II.	2·25	0·045
III.	1·75	0·055
IV.	1·25	0·065

The author points out that if it were required to produce a mixture which would yield after fusion an iron containing 3 per cent. of silicon, no pig iron on the above list would be available, as one would have to be employed, allowing for loss, that would contain 3·45 per cent. This is also the case, too, if an iron with 1 per cent. of silicon is to be made. It would be better, he considers, especially in German practice, to sell, not by numbers, but by silicon contents, increasing by 0·5 per cent. Thus the lowest iron might contain 0·5 to 1·0 per cent. of silicon, the next 1·0 to 1·5 per cent., and the highest 4·0 to 4·5 per cent. The author deals in detail with the practice in mixing different kinds of iron containing varying percentages of silicon so as to produce an iron of a definite silicon contents, allowing for the loss of silicon in each metal on melting. Dealing next with the guarantee to be required, and the personal coefficient of the analyst, the author recommends that it would be well to arrange for some definite method of sampling, and subsequently of chemical analysis, and he strongly recommends the adoption in Germany of some similar method to that in use in the United States, where standard irons in a fairly divided state and carefully analysed can be obtained by purchase from laboratories of repute, for the purposes of control, in case an analyst is doubtful of his own methods.

Specifications for Scrap Iron.—W. G. Scott* proposes the following divisions for scrap iron, and gives the approximate limits for the chemical composition:—

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* *Transactions of the American Foundrymen's Association.* Indianapolis, June 9, 1904, pp. 19-26.

Class.	Si.	S.	P.	Mn.	C.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1. Light machinery scrap	2·00 2·60	0·075 0·095	0·70 0·90	0·20 0·60	3·00 4·25
2. Heavy machinery scrap	1·60 2·20	0·075 0·150	0·40 0·80	0·30 0·90	2·75 4·00
3. Stove plate scrap	2·30 3·30	0·075 0·135	0·45 1·25	0·20 0·70	3·50 4·50
4. Cart wheel and chilled iron	0·50 1·75	0·075 0·150	0·30 0·65	0·30 0·90	2·00 3·75
5*a*. Cast iron borings	1·50 3·0	0·075 0·165	0·30 1·25	0·20 0·90	2·50 4·50
5*b*. Steel borings	0·0 0·50	0·015 0·095	0·015 0·18	0·10 1·00	0·10 1·50
5*c*. Wrought iron borings	0·0 0·15	0·008 0·045	0·011 0·35	0·0 0·15	0·0 0·10
6. Malleable iron scrap	0·30 1·75	0·035 0·095	0·011 0·22	0·15 0·50	1·85 4·25
7*a*. Steel scrap, rails	0·04 0·05	0·025 0·125	0·04 0·14	0·18 1·50	0·20 0·80
7*b*. Steel scrap, castings	0·02 0·50	0·012 0·065	0·02 0·12	0·20 0·80	0·15 0·90
7*c*. Steel scrap, mixed	0·0 0·75	0·005 0·125	0·005 0·25	0·10 1·50	0·10 1·50
8. Wrought scrap	0·0 0·15	0·008 0·045	0·011 0·35	0·9 0·10	0·0 0·05
9. Mixed scrap	...	...	...	...	...

General remarks are given on the kind of material suitable for each class and its proper use.

Austrian Pig Iron.—Cast-iron borings from the Friedland Ironworks in Moravia yielded, according to C. F. Eichleiter,* the following results :—

	Per Cent.
Total carbon	3·254
Graphite	2·927
Combined carbon	0·327
Manganese	0·493
Silicon	1·963
Phosphorus	0·168
Sulphur	0·072

Blast-Furnace Calculations.—A. P. Gaines † describes a method he has evolved for calculating the values of raw material from the analyses in making pig iron, giving a series of fully worked out examples to illustrate the method. Rules are given for determining the theoretical yield of the ore, and the consumption and cost of ore, flux, and fuel, due regard being paid to the flux required for the ash in the fuel.

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. liii. p. 503.

† *Iron Age*, April 14, 1904, pp. 12–14.

According to C. O. Bannister,* several methods have been devised for the rapid calculation of blast-furnace charges, among the most important of which are:—

1. Balling's diagrams, based on the similarity of triangles, which require an arrangement for indicating the position of lines parallel to given lines on the diagram.
2. A method devised by H. C. Jenkins, which requires the use of a slide.
3. A slide-rule devised by A. Wingham.

The method then described by the author is somewhat similar to the second of these, but requires a sheet of squared paper only, no slide or rule being necessary. On this paper lines representing alumina, magnesia, lime, and limestone are marked, and from the analyses of the ore and slag the percentages are taken from the ordinates.

B. Osann † gives analyses of the ferruginous materials used at the blast-furnaces at the Gutehoffnungshütte, near Oberhausen:—

	Percentage of Moisture.	Dried at 100° C.					
		Fe.	Mn.	P.	Cu.	$SiO_2 + Al_2O_3$.	CaO. + MgO.
Phosphoric ores and slags:—							
I.	9·0	34·5	0·3	0·7	...	10·7	18·0
II.	0·2	62·0	0·2	1·1	...	6·5	6·0
III.	15·0	45·0	0·5	1·3	...	19·0	0·8
IV.	30·0	40·0	0·7	3·0	...	14·5	1·5
V.	8·0	48·0	0·5	0·7	...	20·0	5·0
VI.	...	54·0	4·0	3·0	...	13·5	0·5
VII.	...	55·5	0·5	4·0	...	11·0	0·5
VIII.	...	54·0	2·2	2·3	...	18·0	0·7
IX.	...	14·5	3·5	6·7	...	8·0	51·0
Hanover scale	...	51·0	0·5	0·25	...	28·0	...
Manganiferous ores:—							
XI.	9·0	47·0	9·3	0·01	0·20	14·0	4·0
XII.	12·0	50·0	7·0	0·02	0·03	9·0	0·5
XIII.	5·0	35·0	15·5	0·17	0·05	7·0	6·5
XIV.	20·0	23·0	19·5	0·10	0·08	25·0	1·0
XV.	11·0	21·0	20·0	0·03	0·05	15·0	7·5
XVI.	9·0	1·4	50·0	0·17	trace	12·0	trace
XVII.	0·5	4·0	45·0	0·10	0·07	13·0	15·5

I. Minette; II. Grängesberg and Gellivare ore; III. and IV. bog iron ore; V. Caen ore; VI., VII., and VIII. puddling furnace slags; IX. basic Bessemer slag; XI. calcined Siegen spathic ore; XII. Bar el Maden ore; XIII. Greek ore; XIV. Fernie ore; XV. Cartagena ore; XVI. Poti ore; and XVII. calcined Las Cabesses Bordeaux ore.

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* Paper read before the Institution of Mining and Metallurgy, July 21, 1904.

† *Stahl und Eisen*, vol. xxiv. p. 442.

Analyses are also given of the limestones used, of the ash from the coke, and of the slags made. The latter contained 34 per cent. of silica in the case of basic Bessemer iron, 33 per cent. when hæmatite iron was being made, and 27 per cent. when ferro-manganese was being produced, the slag in the latter instance having the following composition:—

SiO_2.	Al_2O_3	FeO.	MnO.	BaO.	CaO.	MgO.	Alkalies.
27·0	11·0	0·3	22·0	2·8	32·0	3·5	0·5

It also contained 1·4 per cent. of sulphur. The basic Bessemer slag contained 11·5 per cent. of alumina and 1·3 of sulphur, while the hæmatite slag had 14·0 of alumina and 1·7 of sulphur, the lime and magnesia contents being respectively 47·6 and 48·5 per cent. The coke used contained 0·8 per cent. of sulphur and 10·5 of ash.

Production of Ferro-silicon from Pyrites and Sand.—R. Amberg* describes experiments which were made with a view to preparing ferro-silicon from pyrites and sand. No good results were attained with gas furnaces, as the temperature was too low. The experiments were therefore continued with the aid of the electric furnace. The first point noted was the extreme volatility of the silica, and an excess of silica was consequently necessary over and above the theoretical requirements of the reaction: $FeS + SiO_2 = FeSi + SO_2$. There was then a considerable quantity of sulphur dioxide formed, and also other products containing up to 20·6 per cent. of silicon, but with considerable quantities of sulphur as well, and it was evident that the above reaction was never complete. Better results were obtained when lime was also added, but even then they were not fully satisfactory, and the author considers that what really happens is that silica is reduced by carbon, and that the silicon so formed expels sulphur from the iron sulphide present, part of the silicon also forming with the sulphur a volatile silicon sulphide.

Ferro-silicon.—According to B. Neumann† eleven German, French, and Swiss works have associated themselves and produce by electric smelting ferro-silicon with 25, 50, and 75 per cent. of silicon. In 1903 about 460 tons of this went to Germany. Analyses

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* *Stahl und Eisen*, vol. xxiv. pp. 394–396.

† *Ibid.*, p. 826.

show it to be very pure as compared with the blast-furnace product:—

	Blast-Furnace.	25 Per Cent. Si.	50 Per Cent. Si.	75 Per Cent. Si.
Iron	83·16	72·70	47·20	23·01
Silicon	10·55	25·80	51·70	75·67
Carbon	2·36	0·48	0·23	0·31
Phosphorus	0·04	0·12	0·06	0·04
Sulphur	0·03	0·04	0·02	0·01
Manganese	3·86	0·86	0·16	0·26

It will be observed that in the products from the electric furnace the carbon and manganese contents are both very low as compared with the product from the blast-furnace.

III.—*BLAST-FURNACE SLAGS.*

Slag Wagons.—F. Frölich [*] describes various types of slag wagon for use in ironworks.

Constitution of Slags.—In a paper read before the German Bunsen Society, Mathesius [†] discussed the constitution of slags. He considers the composition, production, and utilisation of slags which are now divided into ortho- and meta-silicates. Acid slags may be used for direct cement manufacture, but basic slags require treatment with superheated steam. Acid slags from charcoal furnaces may be used for building purposes, but the slags from coke furnaces are less durable as a whole. Such slags should be allowed to weather. The harder parts may then be used, and the disintegrated residue is further reduced with the aid of superheated steam.

Slag Cement.—K. Pietrusky [‡] describes the slag cement industry of the United States, giving numerous analyses of slag cements.

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[*] *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1170–1177, with forty-one illustrations.

[†] *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 319–320, 381–387; *Engineer*, vol. xcvii. p. 584.

[‡] *Chemische Zeitschrift*, vol. iii. pp. 510–512.

J. A. Shinn [*] deals with blast-furnace slag as a structural material, especially with the various forms of slag cement.

The methods of slag disposal in Pittsburg are briefly reviewed.[†]

C. Canaris,[‡] jun., deals with the utilisation of blast-furnace slag and gas. The latter is now utilised as a valuable source of power in suitable gas-engines. The slag is to some extent employed for road-making and as slag wood, but the great increase in the production of pig iron in recent years renders these sources of utilisation quite inadequate, with the result that the waste heaps have been rapidly growing. About the middle of the past century Langen observed the effect that was produced when slag was run into water, and discovered the hydraulic properties of the product. From this time on began a steady, if slow, rise in the slag industry, and this the author sketches. Until quite recently it was customary to look upon slag as simple compounds of acids and bases, including alumina among the latter. Investigations have shown, however, that they are solidified solutions of different substances in one another, while the alumina plays sometimes the part of a base, and at others that of an acid. Various attempts have been made to account for the various properties which slag shows, but it is to K. Zulkowski that the greatest credit is due in this connection. The author has often tested Zulkowski's views in practice, and he deals with them at some length. By a consideration in detail of various slags he shows that granulated blast-furnace slag is nothing but a Portland cement low in lime contents. When slag is added to Portland cement the result is that its hydraulic properties are increased instead of being diminished. Slags slowly cooled down in air show no hydraulic properties at all. Zulkowski explains this as being due to the conversion of the dicalcium meta-silicate into the calcium-ortho-silicate. This the author discusses. He also describes the granulation of the slag in milk of lime.

In experiments made by M. Gary [§] on blast-furnace slags and Portland cements, he found that (1) considered as binding materials the slags examined were not improved by heating to redness, but were rendered less valuable in this respect. (2) The strength of mixtures of binding material and slag rapidly diminish if the mixture is stored for any length of time.

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[*] *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xx. pp. 157–176; see also *Journal of the Iron and Steel Institute*, 1904, No. I. p. 586.

[†] *Iron Trade Review*, June 16, 1904, p. 42.

[‡] *Stahl und Eisen*, vol. xxiv. pp. 813–821.

[§] *Mittheilungen aus den Königlichen technischen Versuchsanstalten*, vol. xxi. pp. 159–169; *Stahl und Eisen*, vol. xxiv. p. 668.

H. Passow,[*] in considering the above results, maintains that the materials experimented with were of an unsatisfactory character, only undried granulated blast-furnace slag having been used. For the iron-Portland cement manufacture only those slags are of value which fuse to a clear glass. The microscope will readily show this. A slag that has lost its glassy character by the separation of lime compounds is opaque, and has passed more or less into a micro-crystalline form, and every works has to find out by actual experiment how this loss of the vitreous character of its slags is best to be avoided. The author next criticises the further methods of treatment adopted by Gary, maintaining that these were altogether different to those which would be employed at works making iron-Portland cement, and indeed had the effect of destroying the necessary vitreous character of a portion of the slags experimented with. Generally, the author contends, these experiments of Gary were wrongly carried out. When properly treated, blast-furnace slag may be made to acquire all the properties of Portland cement. Blast-furnace slag may be granulated by the rapid action of air, and a vitreous product can be obtained in this way. The Portland cement produced in Germany from such air-granulated slag is known as Hansa-Portland cement. Portland cement may be made by grinding together (1) vitreous water-granulated slag with devitrified slag; or (2) vitreous water-granulated slag with ordinary Portland cement; or (3) vitreous air-granulated slag and devitrified air-granulated slag. It is necessary that all the slags ground with Portland cement should possess the same degree of fineness if good results are to be obtained. This is another point, the author maintains, in which Gary's experiments were at fault.

M. Rudeloff [†] gives the results of an elaborate series of tests of armoured-concrete blocks.

Volcanic Action as exemplified by Blast-Furnace Slag.—P. Tabary [‡] describes and figures the formation of miniature cones on the surface of molten slag. One such cone reached over 3 feet in height. He attributes the cause to the gases which are occluded in the slag, and suggests that volcanic action may be largely due to similar causes.

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[*] *Stahl und Eisen*, vol. xxiv. pp. 668–670.

[†] *Mitteilungen aus dem Königlichen Materialprüfungsamt*, vol. xxii. p. 2–8.

[‡] *Annales de la Société Geologique de Belgique; Revue Universelle des Mines*, vol. v. pp. 213–214.

IV.—*FOUNDRY PRACTICE.*

Cupola Practice.—W. H. Carrier[*] gives some data of the operations of cupola blowers in foundry practice, including the air supply per lb. of coke and per ton of iron; the relation of pressure, size of cupola, and speed of melting; the horse-power required for various sizes of cupolas at different pressures, corresponding to the different ratios of melting; the relation of speed pressure and capacity of the blowers; and the effect of piping resistance on the pressure and horse-power. The results are given in plotted and tabular form. The following main points in fan cupola practice should be emphasised: the horse-power required to operate a cupola at any stated pressure is to an extent independent of the size of the blower, so long as it has sufficient capacity to supply the required amount of air. The melting capacity of a cupola under standard conditions varies with the pressure according to fixed laws. More horse-power is required per ton of iron melted at the higher pressures than at the lower ones. At a fixed speed the greatest horse-power is taken when the blower is running wide open, or at free delivery; the least horse-power is taken when the outlet is closed. The increase of horse-power is proportional to the increase in air delivery. The piping resistance decreases the air delivery and decreases the horse-power at a fixed speed, but increases the horse-power when the fan is speeded up to give the same pressure at the cupola. The centrifugal blower presents some advantages over the positive blower, from the fact that better results can be secured at lower pressures, but there is a greater uniformity of blast pressure, and it offers a flexibility in regulation. With the exception of the belting, there is but little wear or deterioration; it will give as high efficiency after running twenty years as when first installed. On the other hand, the positive blower, owing to the friction of the contact surfaces, wears and deteriorates rapidly, and its effect, while high at the beginning, decreases rapidly, owing to the leakage caused by the wearing away of the contact parts.

H. Hess[†] deals with works design as a factor in manufacturing economy, referring, *inter alia*, to the arrangement of the foundry.

The sectional area of cupola tuyeres is discussed by von Wede-

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[*] *Transactions of the American Foundrymen's Association*, June 1904, pp. 46–52; *Iron Age*, June 23, 1904, pp. 12–15.

[†] *Engineering Magazine*, vol. xxvii. pp. 499–520.

meyer.* The author observes that most firms of cupola makers lay much stress upon the use of tuyeres of proper size, but vary widely in the sections recommended. Thus the total tuyere section of one firm may only equal one-fifteenth of the whole fusion zone of the cupola, while with another it may be as much as one half, the figure recommended by Ledebur in his text-book on foundry practice. The author now discusses this subject theoretically, and also details experiments which have agreed with the theoretical deductions, and the results of which are given as a formula. One worked out example shows the tuyeres to possess one-sixth of the section of the fusion zone.

Foundry Appliances.—The arrangement of overhead rails in a foundry is illustrated,† together with details of the switches and carriers.

A number of auxiliary appliances for use in connection with foundry work are described and illustrated by F. Wüst.‡

Foundry Explosion.—Further details are published by Scultetus § of an explosion which took place, and caused six deaths, when a 6-ton chilled roll was being cast at the Halle Foundry. The investigation as to the cause of the explosion which has since been made has led to no definite results. It was found that the metal had broken through the bottom part of the mould, and penetrating into the damp sand had caused an evolution of steam, the pressure of which subsequently blew up the whole of the sand bell, carrying with it large quantities of hot iron granules. This made such a large opening that the whole of the iron from the mould had run into it, forming a shapeless spongy mass. Many hundreds of rolls had been previously cast in a similar manner, and the method by which the mould was prepared is given. The mould itself had not been damaged by the explosion; it was quite empty. A brick had been forced outwards just above the bottom, and through this the molten iron had escaped. Suggestions are made with a view to prevent similar accidents in the future.

German Foundries.—An account is published by F. Wüst || of the Bopp and Reuther Foundry at Waldhof near Mannheim. This was

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* *Stahl und Eisen*, vol. xxiv. pp. 404–406.

† *Iron Trade Review*, July 14, 1904, pp. 36–38.

‡ *Stahl und Eisen*, vol. xxiv. pp. 582-584, with nine illustrations.

§ *Ibid.*, pp. 589–590, with one illustration; *Journal of the Iron and Steel Institute*, 1904, No. I. p. 596.

|| *Stahl und Eisen*, vol. xxiv. pp. 711–716, with four illustrations and one plate.

founded in 1872, and subsequently removed from Mannheim to Waldhof, where extensive works now exist. These the author describes and illustrates, giving a general plan of the whole works, and a plan of the hydraulic accumulator plant worked by two electrically-driven plunger compression pumps, which furnish the power needed for the pig breaker and moulding machines. Other illustrations represent the casting room and other parts of the foundry generally. The cupola house contains 4 cupolas which can melt about 5·5 tons per hour. The daily output, however, at present averages about 20 tons. The blast is supplied by two electrically-driven No. 8 Jäger blowers, used alternately, and delivering blast of a pressure of 32 to 40 inches of water. In 1903 the foundry melted 6164 tons of iron.

Illustrations are published* of the Wupperthal Foundry. In laying down this plant but little ground space was available, and the most had consequently to be made of it. Travelling cranes are largely employed, and details are given as to the general arrangements adopted. The cupolas have spark-catcher attachments, and use pre-heated blast. They melt 5 to 6 tons in an hour with a coke consumption of as little as 5 to 6 per cent. Electricity is largely employed as a source of power. The drying ovens for the cores are coke fired.

Moulding Sand.—E. C. Eckel† enumerates the requisite qualities of moulding sand, and gives a number of analyses of European varieties. Brief reference is made to American sources of supply.

Moulding.—Numerous illustrations of recent moulding machines are given by O. Leyde.‡

B. D. Fuller§ deals with the management of the core bench, the materials used, and the finish of the work.

A. T. Neil‖ also puts forward a plea for the core-maker in comparison with the moulder, and describes the making of cores, for which girls are sometimes employed.

H. F. Frohman¶ offers further remarks on moulding and the use of machinery for core-making.

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* *Stahl und Eisen*, vol. xxiv. pp. 655–657, with three illustrations.

† *Fifty-fifth Annual Report of the New York State Museum*, pp. 91–96.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1036–1040.

§ *Transactions of the American Foundrymen's Association*, Indianapolis, June 1904.

‖ *Ibid.* ¶ *Ibid.*

A report of a committee on insuring patterns contains some remarks on their valuation and depreciation.*

W. H. Parry † discusses pattern-making in relation to foundry costs.

W. S. Morehouse ‡ shows that a moisture limit has not been enforced for moulding sand, and that the general rule is to buy in dry weather.

T. D. West § discusses standard and systematic methods for making hard and soft beds for foundry use. Soft beds are used for open castings without a cope, and semi-hard beds are used for prickered plates. The methods of making the three kinds are dealt with in some detail, and the use of a testing machine ‖ is advocated for determining the proper degree of hardness. Some particulars of the tests are given.

Illustrations are published by F. Wüst ¶ of a method of preparing a mould for casting a branched pipe.

An account is published ** of the drying furnaces employed at the Vulkan Foundry at Stettin. The illustrations show five drying chambers, three of which are at the floor level, while two are arranged above it. The three lower chambers serve for drying moulds, &c., and are about 26 feet long and 10 feet in height. The breadth varies somewhat, the central chamber being about 13 feet wide, while the side chambers are each a few inches narrower. The lower chambers are provided with lines of rails, the door taking up the whole of one side. To prevent loss of heat by radiation, the side walls are made double, an air space being left between them. The firing takes place beneath the floors. A separate system of firing is adopted for the upper set of chambers. These are much smaller than those at the bottom.

In further papers F. Wüst †† describes the methods employed in connection with the making of patterns of various kinds.

Casting Chilled Rolls.—Illustrations are given ‡‡ of the Lincoln plant at Pittsburg for casting chilled rolls. The largest rolls cast here were 227 inches long with a 152-inch face and a diameter of

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* *Transactions of the American Foundrymen's Association*, Indianapolis, June 1904.

† *Ibid.* ‡ *Ibid.* § *Ibid.*

‖ *Journal of the Iron and Steel Institute*, 1904, No. I. p. 598.

¶ *Stahl und Eisen*, vol. xxiv. pp. 583–584, with ten illustrations.

** *Ibid.*, pp. 585–587, with six illustrations.

†† *Ibid.*, pp. 459–462, 773–776, with illustrations.

‡‡ *Iron Trade Review*, July 7, 1904, pp. 64–67.

42 inches. Iron is melted in three 15-ton and 20-ton air furnaces. There are also a 32-foot and 48-inch cupola for supplying metal for sink heads and other purposes. The moulds are placed vertically, and are filled from below through one or two vertical gates.

A plan and illustrations * are given of the Frank-Kneeland plant of the United Engineering and Foundry Company at Pittsburg, where a good many rolling-mills are built. Two 15-ton and one 25-ton air furnace and a 48-inch cupola are used for melting. Two of these furnaces are charged direct from the yard. The ladles pour from the bottom like steel ladles.

Illustrations are given † of a machine for making chilled castings, in which the chill moulds are in halves carried by pivoted frames.

Strengthening Large Cast-Iron Water Pipes.—A method, introduced by Jacquemart, is employed at Paris, in connection with the water supply. The pipes used are about 6 feet 7 inches in diameter, and are of cast iron, cast with grooves on the outside. The grooves are filled with asphalt and then steel wire is tightly wound round the pipe. The pipe itself is stated to be greatly strengthened, while the coating of asphalt increases the life of the steel wire making it equal to that of the cast iron of the pipe. ‡

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* *Iron Trade Review*, May 5, 1904, pp. 64–69.

† *Engineering*, vol. lxxvii. pp. 813, 815.

‡ *Stahl und Eisen*, vol. xxiv. p. 410.

PRODUCTION OF MALLEABLE IRON.

Native Iron Smelting in China.—In a description of the ore and coal fields of south-eastern Shansi in China, W. H. Shockley* gives an illustrated account of the native manufacture in several localities, and corrects several statements made by von Richthofen. All the Shansi iron is made in crucibles. At Yin Ch'eng they are 19 inches in height and 6½ inches in diameter, and are heated in a stall furnace containing 66 pots in an area of 50 by 78 inches with walls 36 inches high. A heat takes 16 hours, and the iron solidifies in the crucibles. Wrought iron is made by heating and hammering the cakes from the crucibles.

Electro-thermal Methods of Iron Manufacture. — B. Neumann † deals with the production of iron and iron alloys by electro-thermal methods. Since 1894 large quantities of poor or impure iron ores have been enriched or purified by means of magnetic separation methods, numerous types of which are mentioned. So far as the commercial manufacture of iron is concerned, electrolytic methods, whether by the ordinary wet method or by means of fusion processes need not be considered. Economical results are not possible in this way. Thus one horse-power would only deposit about 50 grammes of iron per hour by electrolysis, or for the production of a ton of iron 20,000 horse-power hours would be required, a number which suffices to show that nothing is to be hoped for from electricity when employed in this way. Very different results become possible, however, if instead of electrolytic methods electro-thermal ones are employed, the iron being reduced by carbon in an electric furnace. To reduce one ton of iron from its ore 2,300,000 calories are required. In an apparatus yielding 75 per cent. of effective power, about 3800 effective kilowatt hours would suffice,

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* *Transactions of the American Institute of Mining Engineers*, vol. xxiv. pp. 841–871.

† *Stahl und Eisen*, vol. xxiv. pp. 682–688, 761–769, with thirty-four illustrations.

or, say, 5000 kilowatt hours would have to be employed. This is a figure which under certain conditions would not prevent effective commercial competition with other methods of iron production.

As a matter of fact, during the past three or four years a number of methods have been proposed not only for the production of pig iron and iron alloys in this way, but also for the refining of the impure metal. These various methods are dealt with by the author in greater detail and compared with each other from the commercial point of view.

They can be grouped as follows: (*a*) those that use carbon electrodes, and (*b*) those which do not employ them. The former includes the methods of Stassano, Keller, Héroult, Harmet, and Conley, while the latter includes those of Kjellin, Gin, Girod, and Ruthenburg.

It would be possible to group the methods according to whether pig iron and alloys are to be chiefly produced, or whether it is intended to make a steel-like metal with or without the addition of other metals. Many of the methods, however, are intended both to produce the impure metal and also to refine it, and the method of grouping employed above appears consequently the better.

Those processes which do not utilise carbon electrodes are intended solely for the manufacture of steel, while those that employ such electrodes, Conley's alone excepted, employ separate apparatus for the production of the impure metal and for its subsequent refining.

The Ruthenburg method really occupies an entirely separate position from all the rest, partly because the apparatus used is not really an electric furnace and partly because the method does not yield any fluid metal. It forms a kind of link between magnetic separation methods and the fusion process. The Ruthenburg process is employed by the Cowles Electric Smelting and Aluminium Works at Lockport, New York State. Poor magnetites are enriched by magnetic separators until they contain from 65 to 72 per cent. of iron. Owing to the fine state of division of the enriched ores, these products are not suited for all kinds of blast-furnace work, the fine ore running through the coke and reaching the tuyere level in an unreduced form. Binding this fine material together by means of clay, lime, or hydrocarbons does not get rid of the whole of the difficulties, as the briquettes may not allow the furnace gases to penetrate them, or they may break up in the furnace, or yield too much furnace dust. To avoid these difficulties, Ruthenburg passes the concentrates through his furnace, the fusion zone of which is a strong magnetic field. In this way an agglomeration of the ore particles results. If, in addition, carbon is added to the ore before entering the apparatus a partial reduction occurs which is subsequently further completed. The method is described in detail. One apparatus can make six tons a day of the reduced product.

Passing next to the consideration of the methods which depend on the employment of carbon electrodes, the author observes that, historically, they date back to experiments made by W. von Siemens some forty years ago, Sir William Siemens taking out patents in 1878 and subsequent years. The apparatus used was practically a graphite crucible with an iron electrode passing through a hole in the crucible bottom and a carbon electrode passing through a hole in the lid.* In a subsequent modification the electrodes were introduced at the sides. A water-cooled metallic electrode was subsequently used instead of the carbon one. Iron was actually reduced from its ore in this way in 1880, but no practical results ensued from its use. In 1892 an electric furnace was designed by De Laval. Of this the author gives an illustration. From this date, the fresh proposals of this kind, which remained without result, became numerous, many being mentioned by the author, who next deals in detail with the method patented by Stassano in 1898. Illustrations of the older and present forms of the Stassano furnace are given. The process is in active operation in Italy, and it is stated to be easy to produce by its aid either malleable or carburised iron. Very pure ores are used, and analyses are given of the iron ore, limestone used as flux, charcoal employed as the reducing agent, and the pitch used as a binding material in the manufacture of the briquettes. The yield is about 99·7 per cent. of the iron charged, and the following represents an average product:—

Carbon.	Iron.	Manganese.	Silicon.	Sulphur.	Phosphorus.
0·102	99·684	0·094	0·029	0·061	0·017

The ore contained

Fe_2O_3.	MnO.	SiO_2.	S.	P.	CaO + MgO.	H_2O.
93·02	0·62	3·79	0·06	0·06	0·50	1·72

Stassano has also experimented with purple ore containing 1·2 per cent. of sulphur. The pig iron made from it contained 0·06 per cent. of sulphur.

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* This apparatus was shown at the Smoke Abatement Exhibition held at South Kensington in 1882.—E. J. B.

Next the author describes the method devised by Conley. An 8000 horse-power plant to work this process has been erected at Elizabeth Town, United States, and another such works is also to be established there.

The next set of methods described by the author are separate furnaces for the reduction of the ore and for the refining of the product.

The Héroult furnace has undergone many changes since it was first introduced in 1900. In its latest form, as patented in France in 1903, the furnace, as arranged for the production of pig iron, is of the shaft type, the carbon hearth being connected with one pole and another carbon brick higher up in the furnace being connected with the other. The ore enters through a side orifice in a pasty condition and meets with a column of coke, through which the current is passing between the poles. Pig iron is formed, which sinks to the bottom and flows out through an orifice there. Héroult and some others make the pig iron into steel by melting it up with scrap in an electric furnace. De Laval and others endeavour to prevent the absorption of carbon by the steel prepared by the above method by allowing it to remain covered with a layer of slag and passing the carbon electrodes into this, but not quite as far as the metal, leaving instead a thin layer of slag between the two. Another form of refining furnace by Héroult is also described. This is a tipping furnace with tuyeres at the back, something after the style of a converter. These tuyeres are so arranged that the blast can blow upon the metal. Using cold scrap, the inventor states that some 6 or 7 tons of metal are made daily in France, and as much also in Sweden. The process is described.

Another method, that of Keller, is in use at Kerousse, near Hennebout, and at Livet, in the Isère. This process is a dual one. Two furnaces are placed at different levels, the upper acting as a kind of blast-furnace for the ore reduction, while the lower one serves for the conversion of the pig iron into steel. The blast-furnace at Livet yields about 8 tons of steel in the twenty-four hours from ore containing 55 per cent. of iron. The refinery is of the hearth type, with electrodes partially penetrating a surface covering of slag. In this either the ore or the scrap method of treatment of the unrefined metal are employed. Three tons of finished steel are run off at one tap. If the scrap process is employed, then the two furnaces can make 25 tons of steel a day. In the blast-furnace the gases resulting from the deoxidation of the ore are drawn away and burnt, the heat resulting being used to dry the ore. A current of 25 to 30 volts is used in the furnace, but the hearth needs a current of 50 to 75 volts.

The Harmet method does not differ greatly from those just described. A large plant is, however, in course of erection at Albertville, in Savoy. It consists of three superimposed furnaces connected together. The top one acts as a calciner, the middle one as a blast-furnace for the reduction of the fused oxides, and the bottom one, of the hearth type, for the refining of the raw metal. Ore and flux are charged into the calciner, which is heated by the combustion of the gases resulting from the reduction of the ore.

Among the methods which do not use carbon electrodes is that of Kjellin, which is worked on a small scale in Sweden, and that of Schneider, which does not differ much from it in principle. The Gin process is also described, and so too is the electric crucible furnace of Girod, which is intended for the production of iron and iron alloys.

Dealing next * with the consumption of power and the degree of efficiency attained by the various methods, the author observes that, while the reduction of iron by electrical methods is possible theoretically, its commercial success is another question. He considers the question from this point of view, but no definite answer is possible without details as to the cost of the electric power used, which must vary with local conditions. The author then reviews in a similar way the various methods used for the conversion of the pig iron into steel in several of these electric processes. He next discusses the relative costs of the various processes, and then compares generally these electric methods for the reduction of iron with those now in use. He shows that the electric methods may be used with advantage for the production of some of the more costly kinds of special steels, but that, apart from this, the present methods must be those in commercial use.

H. Goldschmidt,† in a paper read before the German Bunsen Society of Applied Physical Chemistry, describes the Ruthenburg electric process of iron reduction. So far only experimental plant has been employed. The ore used is magnetite. It is powdered, concentrated by magnets, and then the fine concentrates are briquetted. This is effected by electrical means, sintering the ore. As the sintered and fused ore falls it is brought into contact with a current of reducing

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* *Stahl und Eisen*, vol. xxiv. pp. 883-888, 944-950.

† *Ibid.*, p. 787.

gases, which are stated to completely reduce it. About 250 kilowatt hours are needed per ton of ore. The operations remove the sulphur, but the phosphorus remains with the iron.

On December 29, 1903, the Minister of the Interior of the Dominion of Canada commissioned Eugene Haanel, superintendent of mines, to proceed to Europe for the purpose of investigating and reporting upon the electro-thermal processes employed in the smelting of iron ores and in the manufacture of steel. The purpose was to ascertain all facts required for determining the feasibility of introducing such processes successfully in Canada. C. E. Brown was designated as electrical engineer of the commission, and F. W. Harbord metallurgist. The localities visited abroad were, in the order named: Gysinge and Kortfors, Sweden; La Praz, France; Turin, Italy, and Livet, France. The report of the commission is a comprehensive work, comprising 223 pages of text, 24 plates, and a large number of diagrams.

In presenting his conclusions, F. W. Harbord states that the process of the electric reduction of iron ore must yet be regarded as in the experimental stage; in fact, no plant exists at the present time where iron ore is commercially reduced to pig iron by the electric process. Two plants were investigated, at which pig iron was being produced. The first was that at La Praz, France, and the second that at Livet, France. Speaking of the results shown there F. W. Harbord says:—

Speaking generally, the reactions in the electric smelting furnace as regards the reduction and combination of iron with silicon, sulphur, phosphorus, and manganese, are similar to those taking place in the blast-furnace. By altering the burden and regulating the temperature by varying the electric current, any grade of iron, grey and white, can be obtained, and the change from one grade to another is effected more rapidly than in the blast-furnace. Grey pig iron, suitable in all respects for acid steel manufacture, either by Bessemer or open-hearth processes, can be produced in the electric furnace. Grey pig iron, suitable for foundry purposes, can be readily produced. Pig iron low in silicon and sulphur, suitable either for the basic Bessemer or the basic open-hearth process, can be produced, provided that the ore mixture contains oxide of manganese, and that a basic slag is maintained by suitable additions of lime. It has not been experimentally demonstrated, but from general considerations there is every reason to believe that pig iron low in silicon and sulphur can be produced even in the absence of manganese oxide in the iron mixture, provided a fluid and basic slag be maintained. Pig iron can be produced on a commercial scale, at a price to compete with the blast-furnace, only when electric energy is very cheap and fuel very dear. On the basis taken in this report, with electric energy at £2 per electric horse-power year and coke at £1, 8s. per ton, the cost of production is approximately the same as the cost of producing pig iron in a modern blast-furnace. Under ordinary conditions, where blast-furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water power is available and blast-furnace coke is not readily obtainable, electric smelting may be commercially successful.

Four plants were investigated in which steel is manufactured. These comprised the Kjellin Works at Gysinge, Sweden; the Héroult Electric Steel Company's plants at Kortfors, Sweden, and La Praz, France, and that of Keller, Leleux & Co., at Livet, France. F. W. Harbord's conclusions as to the results shown by these processes are as follows:—

Steel, equal in all respects to the best Sheffield crucible steel, can be produced, either by the Kjellin or Héroult or Keller process, at a cost considerably less than the cost of producing a high-class crucible steel.

At present structural steel, to compete with open-hearth or Bessemer steel, cannot be economically produced in the electric furnaces, and such furnaces can be used commercially for the production of only very high class steel for special purposes.

In cases where very large steel castings are required of crucible steel quality, several electric furnaces, working so that they could be tapped into a common receptacle, before pouring the steel into the mould, should give excellent results and be much more economical than the crucible process. Under favourable conditions, electric energy might compete with gas as regards cost, but until it is possible to use furnaces of from 30 to 40 tons capacity the extra labour charges inseparable from small furnaces will prevent them from holding their own against the Siemens or Bessemer process.

No report is made on the working of the Stassano electric furnace in Italy, but illustrations of the plant are given.

A report is given on the Ruthenburg process, as demonstrated July 24, 1903, at Lockport, New York, before a special commission. The details of the test are set forth and the conclusions arrived at are stated as follows:—

The fact that the magnetite loses its magnetism before incipient fusion takes place will prevent the agglomeration of the charge in the pit, and the narrow gap between the poles, through which the charge requires to pass, will always render the capacity of the furnace small. These two facts preclude the hope that modifications of the process will render it commercially useful for agglomerating finely divided ore, in substitution of briquetting.

An appendix gives treatises on electro-metallurgy by Henri Harmet, Gustave Gin, Ernesto Stassano and M. Vattier.

A. Minet* deals with the origin, transformations, and applications of the electric furnace. A scheme of classification is proposed and a bibliography is appended. In another place, the author † also deals generally with this subject and describes the various forms of furnaces and their applications to the preliminary treatment of the ore, metallurgy proper, and working the metal.

J. Wright ‡ gives an interesting review of electric furnace processes and their wide application to all sorts of bodies, finishing with steel.

J. W. Richards § deals generally with the various applications of electricity to metallurgy by dry and wet methods.

The electro-metallurgy of iron is dealt with by L. François ‖ and L. Tissier.

The electro-thermal methods of producing iron and steel are described by Troeller.¶

Descriptions and illustrations of the various electric furnaces for iron and steel production are given by A. F. Schneider.**

G. P. Scholl †† describes the manufacture of ferro-alloys in the electric furnace. The alloys dealt with are ferro-silicon, ferro-chromium, ferro-manganese, ferro-vanadium, ferro-molybdenum, and ferro-titanium.

F. Laur ‡‡ describes the works for electric iron smelting at Rome-sur-Bèze. The forge in question is among the oldest in France, and the available water-power, about 600 horse-power, is now to be utilised.

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* Paper read before the Faraday Society, June 9, 1904.

† *Engineering Magazine*, vol. xxvii. pp. 796–816.

‡ *Cassier's Magazine*, vol. xxvi. pp. 24-39.

§ *Technology Quarterly*, vol. xvii. pp. 22-36.

‖ *La Revue Technique*, vol. xxv. No. 13.

¶ *Prometheus*, 1904, pp. 561–565.

** *Mining Magazine*, vol. x. pp. 109–116.

†† *Electro-chemical Industry*, vol. ii. pp. 396, 449–452.

‡‡ *Echo des Mines*, vol. xxxi. pp. 968–970.

It is reported* that the electric smelting of steel has been discontinued at Gysinge for the time being.

Wet Electrolytic Production of Iron.—C. F. Burgess† and C. Hambuechen describe their endeavours to produce electrolytically deposited iron on a commercial scale. They were most successful with an electrolyte containing ferrous and ammonium sulphates. The current density at the cathodes is 6 to 10 ampères per square foot and at the anode slightly less. The electro-motive force for each cell is slightly under 1 volt and the temperature is about 30° C. The anodes consist of ordinary grades of iron and steel and the cathodes at starting are thin sheets of iron freed from rust and scale. About 22 lbs. of iron are obtained per kilowatt-hour and about half a ton of electrolytic iron has been made. Considerable difficulty was encountered in obtaining a uniform deposit, but now sheets can be obtained up to ¾-inch in thickness before the surface becomes too rough and nodular. The cost is placed at about ½d. per pound, which compares very favourably with that of refining copper. The purity is about 99·9 per cent. Carbon is entirely absent, and silicon, manganese, &c., are not present in more than traces. The chief impurity is hydrogen, but that element can be driven off almost completely at a white heat. Its evolutions begins below 100° C. and is rapid at a red heat. The metal containing hydrogen is so hard that it is scarcely touched by a file or saw, and it is exceedingly brittle. After the gas is expelled, the metal becomes softer and approaches Swedish iron in malleability and toughness. It can then be forged and welded, but impurities are introduced in those processes. The sheets can readily be removed from the cathode plates, but are too rough to be rolled. Many attempts have been made to melt this electrolytic iron without introducing impurities, but, so far, much success has not been attained. Hysteresis, permeability, and electric resistance are greatly affected by the amount of hydrogen present. The metal may be used in the production of pure iron compounds, but, owing to the difficulty of melting it without introducing impurities, other fields for its use have yet to be discovered.

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* *Affärsvärlden*, May 20, 1904.

† Paper read before the American Electro-chemical Society, Washington, April 1904; *Iron Trade Review*, May 12, 1904, pp. 40–42; *Iron and Steel Magazine*, vol. viii. pp. 48–54.

FORGE AND MILL MACHINERY.

Forging Presses.—The construction of forging presses is discussed by Peter.* Illustrations of twenty-three types are given.

English Three-High Rolls.—An illustration is given † of a modified form of a three-high plate mill in which the small middle roll is raised or lowered by the lifting tables. The design is due to Calderwood and Parker.

Roll Turning for Girders.—A. Sattmann ‡ reviews the third part of A. Brovot's § book on roll turning, dealing especially in this instance with the shapes to be given to rolls intended for use in rolling beams and special sections. Rails are also dealt with.

Illustrations are given || of some forms of rolls designed by G. B. Johnson for rolling various shapes of reversely curved sections.

Rolling-Mill Engines.—Plans and detail illustrations are given ¶ of a number of tandem compound rolling-mill engines, built at Youngstown, Ohio. The sizes of these engines are 18 and 32 by 36 inches, 24 and 44 by 48 inches, and 42 and 76 by 60 inches. Indicator diagrams are reproduced.

Illustrations are also given ** of the Murray rolling-mill engine, 26 by 48 inches, shown at the St. Louis Exhibition.

Electricity in the Rolling-Mill.—An illustrated description is given †† of a controller for electrically driven rolling-mill tables.

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* *Glasers Annalen*, vol. lv. pp. 61–69.

† *Iron and Coal Trades Review*, vol. lxviii. p. 1840.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 345–349, with five illustrations.

§ Arthur Felix, Leipzig, 14s. per part.

|| *Iron Age*, June 30, 1904, pp. 23–25.

¶ *Ibid.*, July 28, 1904, pp. 11–20.

** *Ibid.*, August 11, 1904, pp. 1–4.

†† *Ibid.*, August 11, 1904, pp. 4–5.

P. R. Allen * treats of electric machinery in steelworks in a well-illustrated article.

H. Rupprecht † discusses the development of the electric driving of rolling-mills.

A condensed translation of C. Köttgen's paper ‡ on electrically driven rolling-mills has been published.§ The matters dealt with are three-high mills, regulation of motors, balancing the power, electric driving compared with gas-engines, roll tables, and reversing-mills.

A Manipulator for a Blooming-Mill.—A small plan is given || of a manipulator for a blooming-mill at Cortland, New York. This mill is a 25-inch reversing-mill and rolls thirty ingots per hour from a section of 12 by 14 inches into 1¾-inch squares. The manipulator is worked hydraulically and acts also as a movable guide.

Wire-Rod Mills.—Illustrations are given ¶ of two-high and three-high mills for rolling wire rod and bars, and of the furnaces used for heating the material, to illustrate English and German practice. J. J. Bleckly points out that some of his own designs are preferable.**

The new wire-rod mill at the Tinsley Works of W. Cooke and Company, Ltd., at Sheffield has recently been opened.†† The mill is driven by a pair of coupled tandem compound condensing engines with 16- and 28-inch cylinders with a 42-inch stroke through a rope drive.

Continental Sheet Rolling-Mills.—A plan is given ‡‡ of the new sheet rolling-mill at the Charlottenhütte, Niederschelden, Germany. It includes two heating furnaces, 50 feet in length, equipped with hydraulic pushers. The mill is driven by a tandem compound engine with a stroke of 4 feet and cylinders 3 feet by 4 feet 7 inches in diameter. The three-high train has rolls 10½ feet in length, the middle roll being 2½ feet in diameter, and the others 3 feet. A second three-high mill of smaller size is used for thinner sheets.

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* *Electrical Magazine*, July, 1904.

† *Centralblatt der Walzwerke*, vol. viii. p. 476.

‡ *Stahl und Eisen*, vol. xxiv. pp. 209–237.

§ *Iron Age*, May 19, 1904, pp. 20–24.

|| *Iron and Coal Trades Review*, vol. lxviii. p. 1052.

¶ *Engineering*, vol. lxxvii. pp. 776–779, with plate.

** *Ibid.*, vol. lxxviii. p. 15.

†† *Iron and Coal Trades Review*, vol. lxix. pp. 111–112.

‡‡ *Ibid.*, p. 32.

A. Ruhfus* describes the new plate rolling-mill of the Charlottenhütte at Niederschelden, on the Sieg, Germany.

Illustrations are given of the three-high universal rolling-mill at the Burbach Ironworks.† The principal dimensions of the mill are as follows: diameter of the top and bottom rolls, 27½ inches; diameter of the middle roll, 22 inches; maximum opening, 13¾ inches; diameter of the vertical rolls, 19¾ inches; diameter of the pinion, 26 inches; lifting table (measured from centre of rolls), 46 feet long; width of the lifting table, 49¼ inches; hydraulic pressure at disposal, 370 pounds per square inch; steam pressure, 73 pounds. The mill is constructed to roll a 3-ton ingot into plates of any width from 6 up to 40 inches, with provision made for a possible raising of the upper limit to 43·5 inches.

Illustrations are published of new rolling-mills constructed at Duisburg, and erected at various German works.‡

L. Delacuvellerie§ describes the plant recently laid down by the Société de Sambre et Moselle, at Montigny on Sambre. There are 24 soaking pits for the reception of the ingots, which are first taken on the bogie straight from the casting pit to the hydraulic stripper, and thence, by means of an overhead traveller, to the pits. The cogging-mill consists of a train of rolls in a pair of housings, one for the pinions, and the other for the rolls themselves. The distance between the rolls is controlled by a hydraulic machine. The train is driven by a compound double tandem engine, on the Sach and Kisselbach system, built at Seraing. It is geared 5 to 2 on to the rolls. On each side of the latter is a train of line rolls driven by a 40 horse-power electric motor. A 20-ton overhead traveller, of 36-feet span, worked by 3 electric motors of 15 horse-power each, is installed above the mill, and the usual tilting appliances, saws, and shears are also provided. The central electric station whence power is derived for the various motors comprises two Carels-Dulait machines, each consisting of a twin-cylinder compound engine, coupled directly on to an alternating motor of 450 kilowatts at 600 volts. A third group of a Waelschaerts compound tandem 75 kilowatts generator, and a 45 horse-power excitor, for the Carels-Dulait groups, are also provided.

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* *Stahl und Eisen*, vol. xxiv. pp. 622–624, with two illustrations.

† *Iron and Coal Trades Review*, vol. lxviii. pp. 1279–1281.

‡ *Stahl und Eisen*, vol. xxiv. pp. 869–873, 929–934, with ten illustrations.

§ *Annales des Mines de Belgique*, vol. ix. pp. 563–565.

E. Richarme * describes several rolling-mills for blooms, billets, girders, and rails, and calculates the power needed. He gives drawings of the Droujkofka rail-mill, of a two-high blooming-mill, of a two-high finishing-mill, and a twin compound rolling-engine.

The construction of rolling-mills is discussed by W. Jansson.† He gives a detailed description of the mill at Fagersta, with dimensioned drawings.

A small plan and elevation are given of the three-cylinder reversing engine of 6000 horse-power at the Nishni Saldinsk Works in the Ural. They run at 100 revolutions, and roll rails in seven passes. It is calculated that the horse-power required per kilogramme of the metal amounts to 13 in the last pass, and 9 in the last but four.‡

American Rolling-Mills.—A plan and illustrations are given § of the steel plant of the Grand Crossing Tack Company, near Chicago. Steel is made in two 40-ton basic open-hearth furnaces. A 36-inch blooming-mill reduces 4700-lb. ingots to 1¾-inch square billets without reheating in one pair of rolls. The ingot is reduced in 19 passes to a 4-inch billet, and then the mill is run continuously, instead of reversing, repeaters being employed to conduct the billet round the housings into the mill, in order to reduce it to the finished size of 1¾ inch square and 450 feet in length. The time taken is 4 to 4½ minutes. This mill is driven by a three-cylinder 40-inch engine, of which plans and continuous indicator diagrams are given. The billet is cut into 30-foot lengths, which are rolled into rod in a Morgan continuous mill.

The Monterey rolling-mills, Mexico, are described by O. Goldstein, ‖ who states that the Monterey Steelworks were founded in consequence of the rapidly increasing consumption of iron and steel in Mexico. The selection of Monterey as the site of the steelworks was due to its being situated in the midst of important deposits of coal and ironstone, while it also has excellent railway communication. A blast-furnace and open-hearth plant of modern American design have been erected, and in addition a large rolling-mill plant. This the author describes. The ingots dealt with are of the average weight of 1 ton.

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* *Bulletin de la Société de l'Industrie Minérale*, vol. iii. pp. 119–184, 371–479, with four plates.

† *Jernkontorets Annaler*, vol. lix. pp. 142–153.

‡ *Iron and Coal Trades Review*, vol. lxviii. p. 1050.

§ *Iron Age*, August 4, 1904, pp. 16–21; *Iron Trade Review*, August 4, 1904, pp. 60–64.

‖ *Stahl und Eisen*, vol. xxiv. pp. 689–693, with five illustrations.

There are three trains of rolls, the dimensions of which are given, as well as illustrations showing the general arrangement of the plant.

Rolling-Mills in Japan.—C. E. Heurteau [*] describes the machinery and appliances in use at the Imperial Wakamatsu Works at Kiushiu. They are capable of turning out 140,000 tons of finished material per annum.

Forged and Rolled Railway Wheels.—H. V. von Z. Loss [†] describes the manufacture of forged and solid rolled railway wheels, incidentally comparing them with chilled cast wheels. Blanks or ingots, 4 inches less in diameter than the finished wheel, are submitted to a 5000-ton press, which reduces the thickness, forms the hub, and punches the central hole. The forged blank is then transferred to the mill, in which the web is rolled down further and the tread partly formed, the final conical shape being given in a second forging press. The three operations are done in one heat, and a good deal of automatic machinery is used for transferring the wheels and for controlling their size. Illustrations of the plant are given, and also some photomicrographs to show the improvement in the metal by these processes. The metal used contains:—

C.	Mn.	Si.	S.	P.
0·7	0·65 to 0·7	0·3	below 0·05	below 0·05

Physical tests show an elongation of 13 per cent. in 2 inches, with a contraction of 35 to 40 per cent., and an ultimate strength of 125,000 pounds.

Power Costs at a Large Works.—K. Iffland [‡] considers the question of the cost of production of power at a large works. Until about 1885 the steam-engine was practically the sole source of motive power employed at smelting works, apart from the occasional use of water-power. Gas-engines of small size were built, but they used the costly illuminating gas. They were therefore only at work in the vicinity of gasworks, and for subordinate purposes. Electromotors were also employed in a similar way. The use of the latter, however, soon spread. Machinery made rapid progress after the eighties, and

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[*] *Annales des Mines*, vol. vi. pp. 113–117.

[†] *Journal of the Franklin Institute*, clvii. pp. 333–354; *Iron Trade Review*, May 5, 1904, p. 94, May 12, 1904, p. 35.

[‡] *Stahl und Eisen*, vol. xxiv. pp. 693–710.

electro-technology developed at a rapid rate. Gas-engines grew larger and larger, and illuminating gas as a source of power gave place to gas of a less expensive character. The author deals generally with the question of the selection of the source of power, when—(1) all parts of the works are served direct by steam-engines; (2) all parts of the works are served direct with blast-furnace gas-engines; (3) all parts of the works are served exclusively by electromotors, driven by blast-furnace gas-engines; and (4) all parts of the works are served by electromotors, driven by steam-turbines.

The author's data are based on actual results in practice. Very full detailed statements are given in tabular form, the first relating to the coking plant, and the second to the blast-furnaces and those portions of an ironworks directly connected therewith. The next table deals with the steelworks side of such a works, while other tables relate to the rolling-mills, secondary operations, and mining. The total first costs and annual working charges for the four different types of power as applied to one and the same works the author summarises as follows:—

Type.	First Cost.	Annual Charge.
	£	£
1	330,000	280,000
2	300,000	165,000
3	390,000	145,000
4	357,500	132,500

The total normal yield of all the motors is estimated to amount to 20,843 effective horse-power. The author further summarises the reasons which should determine the choice between gas motors or steam-turbines for driving the dynamos at a central generating station.

PRODUCTION OF STEEL.

CONTENTS.

I.—*THE CARBURISATION OF MALLEABLE IRON.*

Cementation.—The cementation of carbon steels and of special steels is described by L. Guillet.* He explains the processes of cementation, and discusses the influence of the carbon contents, of the duration of the process, and of the fluxes. Reference is made to the cementation of nickel steel, of manganese steel, and of tungsten steel. Notes on cementation are also given by G. Charpy.†

II.—*THE OPEN-HEARTH PROCESS.*

Development of the Open-Hearth Processes.—R. M. Daelen ‡ considers various methods which have been adopted for the manufacture of steel in the open-hearth furnace. Since its introduction in 1866 the open-hearth process has made steady progress, and several modifications both in the furnace used and in the process itself have arisen. In Germany the basic Bessemer process is still the most commonly employed, but in other countries this process has been largely superseded by open-hearth methods. For Germany, the author considers the basic Bessemer process is commercially the best adapted to meet local conditions. He compares the two processes from this point of view, and then refers to the mixed Bessemer and open-hearth process. In 1898, L. Pscholka and the author attempted to

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* *Mémoires de la Société des Ingenieurs Civils de France*, 1904, No. 1, pp. 177–207.

† *Iron and Steel Magazine*, vol. viii. pp. 301–309.

‡ *Stahl und Eisen*, vol. xxiv. pp. 507–514, with ten illustrations.

submit the pig iron to a preliminary fining process at the blast-furnace itself, using the same blast. A simple form of converter was used, of which an illustration is given, and good results, though not final ones, were obtained. The experiments were continued elsewhere. The author shows how the shape of the converter became modified. The Bertrand-Thiel and the Talbot processes are next dealt with, and considered at some length.

J. A. Brinell * gives a brief description of the recent modifications of the open-hearth process introduced by Talbot, by Bertrand-Thiel, and by Monell.

Electric-Charging Machine.—It is pointed out † that less than ten years have elapsed since the first electrically-driven charging machine for open-hearth furnaces was erected in Europe. The first one put into operation was at the Riesa Ironworks of the Lauchhammer Company in 1895. Since then, however, their use has spread very rapidly, as it was soon recognised that a saving in labour charges and in fuel costs resulted, while the duration of a furnace charge was considerably reduced. Not only steel furnaces, but heating furnaces also have been largely equipped with these machines, and illustrations are given of an apparatus designed at the Lauchhammer works. Six electromotors are mounted on the machine. Two serve to move it along a line of rails running parallel to the furnace, and the others serve to turn it, and to operate it generally. Each motor can be operated independently. General details are given as to the construction of this appliance, and it is claimed that by its use very considerable saving can be effected. One man suffices for a whole row of furnaces; fuel is saved; the duration of the charge shortened; the machine occupies very little space; furnaces lying at angles to each other can be charged; ingots of any size and shape can be manipulated, and other advantages of a similar character are realised.

Lime Flux for the Open-Hearth.—D. Baker ‡ gives his experience in calcining limestone for use in the basic open-hearth furnaces at the Dominion Works, Sydney, Nova Scotia. From 100 to 120 tons of lime are required daily, delivered into the charging boxes. The limestone used is a pure marble obtained from a distance of 65 miles and containing less than 1 per cent. of silica. It is broken

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* *Teknisk Tidskrift, allmänna Afdelningen*, vol. xxxiv. pp. 250–253.

† *Stahl und Eisen*, vol. xxiv. pp. 642–647, with four illustrations.

‡ *Iron Age*, April 21, 1904, pp. 6–7.

to pass a 10-inch ring. Raw coal and raw coke-oven gas gave too much sulphur, so tar was employed as fuel with success, but owing to its cost has been replaced by gas purified by bog ore and washing. The kilns are fitted with specially designed discharging valves for the burnt lime and the raw stone is charged by mechanical means.

Valves for Regenerative Furnaces.—A. D. Williams * discusses the use of various types of valves for regenerative furnaces and deals with the fuel losses involved. The ordinary Siemens butterfly valve is simple and quick in its action, but is liable to leakage, especially when it is burnt, and cooling arrangements make many complications Slower valves are not so liable to leakage, but lose more gas during reversal. Water seals have many disadvantages, as they require constant supervision, and the evaporation of water from them is very deleterious. Calculations are then given to show the losses in a 50-ton furnace, making fifteen heats weekly with a coal consumption of 772 lbs. of coal per ton of steel. The diameters of the air and gas valves are 48 and 40 inches respectively, and it takes about fifteen seconds to reverse the valves, this being done four times hourly. The results of the investigation show a loss of about a ton of fuel per heat.

Illustrations are given † of the Wight and Hyatt water seal valve.

Saving Gas in Reversing.—C. Ritter von Schwarz ‡ draws attention to an arrangement proposed by Kurzwernhart for entirely avoiding the gas losses which have hitherto occurred in reversing. It provides for an opening as near as possible to the point at which the gas is cut off. Air enters through this, and a current passes towards the regenerators instead of the customary gas current driving the residual gas before it into the furnace. The description is accompanied by an illustration. This method has now been in constant use for many months at the Teplitz Ironworks, and may be employed with any of the existing reversing methods.

The Bertrand-Thiel Process.—The results obtained with the Bertrand-Thiel process at the Hösch Steelworks are described by Pottgiesser.§ Basic pig iron is used, and two ordinary 18-ton open-

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* *Iron Age*, April 7, 1904, pp. 22–23.

† *Ibid.*, April 28, 1904, pp. 14–15.

‡ *Stahl und Eisen*, vol. xxiv. pp. 619–620.

§ *Ibid.*, pp. 620–621.

hearths are employed. Each of these has a small door opening to enable it to be employed as a preliminary or finishing fining furnace. The iron taken from the mixer contains about:—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
3·0	1·5	0·3	1·8	0·07

Into the preliminary fining furnace solid basic pig iron, ore, and limestone are charged, and when this charge has become pasty molten iron is added from the mixer. A rapid reaction results necessitating the gas being shut off for a while. When the reaction lessens, the charge may be tapped if the charge of ore, limestone, and scrap in the finishing furnace has become thick fluid. As it is not a matter of importance that the metal to be charged into the finishing furnace shall contain any particular percentages of carbon and phosphorus, there is no chance of the operations in the two furnaces clashing with each other. The percentage of carbon in the metal after leaving the first furnace varies between 1 and 2 per cent. and that of the phosphorus between 0·1 and 0·3, while the slag made in this furnace contains up to 25 per cent. of phosphoric acid (P_2O_5). The charge is tapped from the first furnace into a ladle and then run into the second furnace. The duration of a charge in each furnace is about 2·5 hours, but when a better method of charging becomes possible this will probably be reduced to 2 hours or even less. The yield is at least 103 per cent. if the ore added is not considered. The fuel required is no greater in quantity than is needed for an ordinary open-hearth, while the steel made is very low in phosphorus, casts and rolls well, and is of uniform quality. A saving of at least four shillings per ton of finished metal has been effected, as compared with the ordinary open-hearth methods previously in use. The author observes that this method gives the best results where fluid pig iron is available, preferably that from a pig-iron mixer.

Continuous Open-Hearth Process.—O. Thiel[*] discusses the process of continuous working in fixed open-hearths described by S. Surzycki, and then gives details as to the results attained by the use of the Bertrand-Thiel process. At Czenstochau, using the former method, two 27-ton furnaces have a constant make of about 130 to 140 tons, and from two 50-ton furnaces a steady output of from 150 to 180 tons is obtained. Under similar conditions, the author contends that, from the two smaller furnaces, by using the Bertrand-

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[*] *Stahl und Eisen*, vol. xxiv. p. 458.

Thiel process, a yield of from 250 to 270 tons would result. Thus, at the Hösch Steelworks, there is worked off with two furnaces in the twenty-four hours ten charges of about 19 tons each, the metal being finished in the furnace itself. The first furnace takes a charge of 1 ton of solid basic pig iron, 3·5 tons of Swedish magnetite containing about 63 per cent. of iron, 1·1 ton of limestone, and 14 tons of molten basic pig iron from the mixer. The slag obtained in this preliminary fining furnace contained from 20 to 25 per cent. of P_2O_5. The second or finishing furnace takes as its charge 0·4 ton of Swedish magnetite, 0·4 ton of roll scale (containing about 70 per cent. of iron), 0·7 ton limestone, and 3·5 tons of scrap, in addition to the metal from the first furnace. The pig iron used contains about:—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
3·0	1·0	0·3	1·8	0·07

The phosphorus contents of the finished metal is of a very even character, as the author shows in the case of ten charges. The first contained 0·010 phosphorus; Nos. 2, 3, and 4, 0·025; No. 5, 0·020; No. 6, 0·025; No. 7, 0·030; and Nos. 8, 9, and 10 each 0·025. Thus of the ten charges no less than seven yielded metal of the same phosphorus contents. The yield is at least 103 per cent., the product being of a very good quality generally.

The Talbot Process.—R. M. Daelen * gives some notes on open-hearth and mixed processes, and deals specially with the Talbot process. The economy of the process may be due in part to the diminished loss by radiation from the large furnace and to the greater speed of heating. The economy in production, due to the large amount of iron reduced from the ore, is also discussed.

The Monell Open-Hearth Process.—C. W. Tideström † observes that the so-called Monell process is in use at the Homestead Steelworks, United States. It is based on the use of molten iron, and consists in charging limestone, ore, and pig iron in the following manner: the hearth bottom consists of magnetite, and upon it is first charged in 3 tons of limestone, next from 1·0 to 1·2 ton of pre-heated ore is charged, according to the silicon contents of the pig iron to be used. At the end of about ninety minutes, when the

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* *Iron and Coal Trades Review*, vol. lxviii. pp. 2030–2032.

† *Bihang till Jernkontorets Annaler*, 1903, pp. 351–368, 389–401, with five illustrations.

ore is near its melting point, 40 tons of molten pig iron are added direct from the blast-furnace. A violent reaction ensues, and as the temperature is relatively low and favourable to the elimination of the phosphorus, it is oxidised and passes out with the silicon and manganese, a thick foaming slag covering being produced. At the back of the furnace is a slag tap-hole about 4 inches above the surface of the bath of steel, and through this the slag is allowed to run away. About two hours after the pig iron was charged in, the silicon is found to have been oxidised away, together with most of the phosphorus and manganese. The large quantity of slag that has formed is tapped off and the bath of metal is kept covered with only a thin coating of slag. The pig iron used contains:—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
3·90	0·5 to 0·9	0·8 to 0·9	0·5 to 0·8	0·04 to 0·07

The ore used has the following composition:—

Iron.	Silicon.	Manganese.	Phosphorus.
64·0	3·0	0·1	0·1

The slag produced contains:—

Silica.	Iron.	Phosphoric Acid.	Lime.
20·0	20 to 25	3 to 5	20 to 25

and the steel made:—

Carbon.	Phosphorus.	Sulphur.	Manganese.	Silicon.
2·00 to 2·50	0·04 or less	0·04	0·10 to 0·15	trace

In consequence of the slag coating being thin, the gases act rapidly on the metal, bringing it to a good temperature, and, together with the action of the residual ore, eliminating still more of the carbon. About sixteen to eighteen heats per week yield 650 to 700 tons of ingots, the yield of iron being 100 to 102 per cent., and the duration of the charge 7·5 to 8·5 hours.

French Steelworks.—An illustrated description has been published* of the new open-hearth steelworks erected for the French Government at Guérigny. The plant comprises two basic open-hearth furnaces of 12 and 18 tons and a battery of six Poetter gas-producers.

New Open-Hearth Plants.—New open-hearth plants are now being laid down by the Georgs-Marien Company at Osnabrück, the Bismarck Works in Upper Silesia, and at Ilsenburg in the Harz.†

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* *Echo des Mines*, vol. xxxi. pp. 922–924.
† *Stahl und Eisen*, vol. xxiv. p. 671.

Open-Hearth Steel Plant at Thale.—In a paper read before the Verein zur Beförderung des Gewerbfleisses, H. Wedding * described the Thale Ironworks. In 1188 there were forges at Walkenried, in 1237 on the Brunnbach, a tributary of the Bode, and in 1355 at Tanne. These were usually situate on the hills in the midst of forests, in places where, in addition to being able to get ore, it was most easily possible to obtain charcoal in quantities. After the introduction of the blast-furnace method, the iron industry migrated from the hills to the valleys, with a view to the utilisation of the available sources of water-power. The valley of the Bode in particular was selected in this way, and so far back as 1500 there were eight ironworks there. After the introduction of coal as a fuel in blast-furnace practice, the iron industry of the Harz began to dwindle, and to-day there are only a few ironworks on the Bode making pig iron with charcoal, such as Rotehütte and Rübeland. The first period of the modern Thale Ironworks can be traced back to an early time. In 1740 it belonged to a company, but was reorganised by Frederick the Great in 1770, and passed into the possession of the king in 1778, who enlarged the plant. In 1786 the works again passed into private hands, and after passing under various ownership, became in 1872 the property of a company, which has since very greatly enlarged the plant. It now possesses two open-hearths, which were originally intended to take charges of 25 to 30 tons, but at the end of 1903 they were so enlarged that charges of 55 tons can now be dealt with. Each furnace makes about 200 tons per day or 60,000 tons per annum. In view, however, of the repairs which the plant needs from time to time, the total annual output of this open-hearth plant is only 90,000 tons. The charge contains 20 to 22 per cent. of pig iron, which is obtained from Westphalia. The scrap also used is obtained one-half on the spot and the remainder from Central Germany. Metal is produced which contains:—

Carbon.	Phosphorus.	Manganese.	Silicon.
0·05 to 0·08	Below 0·03	0·25 to 0·35	0 to a trace.

This is an iron which has from 30 to 35 per cent.. elongation and about 60 per cent. reduction of area. The rolling-mills and other plant are also described.

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* *Stahl und Eisen*, vol. xxiv. pp. 918–919.

Hungarian Steelworks.—A detailed description of the Rombach Steelworks has been written by B. Neuherz.* A plan of the works is given with illustrations of the blast-furnaces, the Bildt gas-producer, the 600 millimetre three-high rolling-mill, and other appliances.

New Open-Hearth Plant at the Duquesne Steelworks.—A further account of the new plant of the Duquesne Steelworks is given by C. W. Tideström,† who has visited various steelworks in the United States. This plant comprises twelve 50-ton open-hearths. The furnaces use natural draught, and the author gives their dimensions, as well as those of the other parts of the plant. The method of lining is also described. Each furnace is internally about 27 feet long by 13 broad. Magnesite, dolomite, or chrome iron ore is used for the basic or neutral portions of the lining and strongly siliceous material for the roof. The dimensions of the kilns used for calcining the dolomite needed are given. In their first campaign six of these furnaces lasted in the average 400 charges. After this the roofs fell in. The furnace walls would have lasted much longer, and the regenerators were found to be still in good working order.

If molten iron is charged into the furnace, then during the first portion of the resulting rapid boil a large quantity of iron oxide is observed to escape from the stack, which tends to keep the regenerators free from dust. The charge consists of about 26·3 metric tons of pig iron, usually molten, a similar quantity of scrap, 3·6 tons of limestone, and 0·9 to 1·4 ton of hæmatite. In the basic process the slag base is chiefly lime, ferrous oxide playing a subordinate part, while in the acid process a very large part of any iron ore charged passes into the slag, as a base for the neutralisation of the silica present. Consequently in the basic process the quantity of iron ore that is required as an addition is much less than when the acid method is used. The influence exerted by the lime also added begins to show itself in the basic process during the characteristically strong boil, as spongy lumps of slag rise to the surface and gradually pass into the basic slag that is so necessary for the elimination of the phosphorus. After the first period of the boil is over, samples are taken to determine the carbon and the quantity of ore calculated necessary to reduce this to about 0·01. If the lime that is added at first is rapidly taken up and a thin slag formed, it proves that the original bath was more than usually siliceous, and that more lime must be added.

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* *Banyaszati es Kohaszati Lapok*, vol. xxxviii. pp. 81–92.

† *Bihang till Jernkontorets Annaler*, 1903, pp. 389–401.

As soon as the spongy masses of lime have melted down into the slag, either fluorspar or a by-product from soda manufacture is added, an analysis of which is given. Fluorspar is a very useful addition, as it thins the slag and enables it to dissolve more lime, but it must not be used before the carbon has been reduced to 0·2, neither must too much of it be added even then, as the slag foams up. The power that a slag possesses of dissolving phosphorus is chiefly dependent on its basicity, and at the same time on its fusibility, and the latter is in turn dependent on the number and quantity of the bases that have passed into it. When the samples above referred to are taken, if the slag remains in the ladle without having specially to be held back, it is probably of good quality. It must, however, spread out evenly, and must not form pasty lumps. A slag that is too viscous separates badly from the iron, and is not easy to remove from the furnace walls. Basic open-hearth slags usually contain:—

	Per Cent.
Silica	17·70 to 24·35
Ferrous oxide	15·30 ,, 10·90
Manganous oxide	7·70 ,, 5·32
Lime	38·75 ,, 39·15
Magnesia	6·60 ,, 7·58
Phosphorus pentoxide	13·95 ,, 12·70

Complicated hammer tests are never made in the United States. High carbons are always determined by a rapidly performed preliminary colorimetric test, and low carbons by the fracture of the sample hardened when the iron is still at a white heat. With these tests the author deals. Aluminium is largely used, generally in the pan, but sometimes in the form of small pieces added to the metal in the moulds. In the larger basic open-hearth plants it is used chiefly as a quieting agent for too lively metal.

Canadian Open-Hearth Plant.—A plan is given * of the open-hearth plant of the Dominion Company, Nova Scotia.

III.—*THE BESSEMER PROCESS.*

Mixers.—Illustrations are given † of a special form of mixer designed by J. Kennedy for strength, economy of materials of construction, and reduction of the liability to skull. It is charged

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* *Iron and Coal Trades Review*, vol. lxix. p. 114.

† *Engineering and Mining Journal*, vol. lxxvii. pp. 808–809.

through a counterweighted door at the top, and has a tapping opening at the side above the centre.

Preliminary Refining in the Converter.—R. M. Daelen* describes his conjoint experiments with L. Pscholka on the preliminary refining of pig iron in the converter, preparatory to finishing in the open-hearth. At Krompach, in Hungary, a 10-ton fixed converter of box shape was used, and was blown with hot-blast through inclined tuyeres, placed at the level of the surface of the bath. With iron containing 3·5 per cent. of carbon, 2·2 of manganese, and 1 per cent. of silicon, there was a waste of 7·29 per cent. in bringing the carbon down to 1 per cent. The principal advantage consisted in the reduction of the cost of the finishing process of melting in the open-hearth furnace; for if with the ordinary scrap melted with cold charges and containing 1 per cent. of carbon, there could be obtained six meltings within twenty-four hours, seven such meltings may certainly be reckoned upon in regular working with liquid preliminary-refined pig iron, in addition to which the reduction of coal consumption in the open-hearth furnace is considerable, amounting as it did to 3 cwt. per ton of output, compared with 5 to 5½ cwt. with the scrap melting. Further trials were made at Czenstochau and Rheinhausen with a rolling type of converter of 20-tons capacity, but were unsuccessful owing to failure of the lining. A cylindrical type of converter is proposed, and of this form sections are given.

Small Converters.—An illustrated description and plan are given † of the Tropenas converters at the Sargent steel foundry, Chicago Heights. There are three converters, each making 24 tons daily in charges of 5000 lbs.

The various types of small Bessemer converters are discussed by F. Wüst.‡

H. Braune § describes the small Bessemer converter, with admixture of oxygen to the blast, invented by C. Raapke. Drawings are given showing the construction of the converter of this type used at Kapeln, in Holstein. The converter was very small, holding charges of about half a ton. The pig iron was tapped direct into the converter from a cupola, and blast was supplied by a 10 horse-power

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* *Iron and Coal Trades Review*, vol. lxviii. pp. 2030–2032.

† *Ibid.*, pp. 1913–1914.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1117–1120.

§ *Bihang till Jernkontorets Annaler*, 1904, pp. 173–190.

blowing-engine. Raapke's new converter, the outcome of experience with the older one, consists of two parts, a lower or converter proper, and an upper one containing the apparatus for utilising the heat evolved. The lower consists of a box of sheet metal suspended in trunnions and lined with 200 to 300 millimetres thickness of silica brickwork, forming a flat-bottomed furnace with flat sides and a slightly arched roof with a chimney aperture. The chimney is made of thick sheet metal lined at the bottom with firebrick, and at the top with cast iron. In order to obviate loss of heat after a blow the chimney is furnished with a balanced lid. On the first side of the furnace are arrangements for receiving the pig iron and for tapping the converter, both apertures being provided with lids. On the rear side of the furnace there are the tuyeres, and this side, which is inclined, can be removed for repairs. The tuyeres are placed in a row, and are inclined towards the flat bottom, above which they are 150 to 200 millimetres. They are five to seven in number, and blow parallel to the length of the furnace. The converter is tapped by hand. In the upper part of the converter the oxygen gas is prepared and the blast heated. The oxygen is prepared by Tessié du Motay's method of heating a mixture of sodium hydrate with manganese oxide in a current of air. For one ton of charge 100 kilogrammes of manganese oxide are required, or 80 kilogrammes for a 800 kilogramme charge.

The converter is made in four sizes for charges of 0·8, 1·6, 2·25, and 3·5 tons, the normal and maximum power required for the blast being respectively 15 and 35, 30 and 65, 50 and 95, 80 and 165 horse-power respectively. Thus about 22 horse-power is required per ton charge, whilst in Sweden the power consumption is five or six times as much. This great advantage is due in the Raapke process to the fact that the blast enters on the surface of the metal. A Bessemer blow by the Raapke method proceeds as follows: In the cupola with 10 to 20 per cent. of scrap and with good coke free from sulphur, Bessemer pig with about 4 per cent. of carbon, 3 to 4 per cent. of silicon, 0·8 to 1 per cent. of manganese, 0·03 per cent. of sulphur, and 0·06 per cent. of phosphorus, is smelted. In a well-constructed cupola 12 to 15 kilogrammes of coke is used for melting 100 kilogrammes of iron. At the same time the converter is heated with coke. The molten iron is run in and the cover of the charging hole closed. The blast is turned on and the converter tilted backwards a little. The blast passes under the metal and the refining begins.

After a time the flames from the chimney acquire a brighter colour. The converter is then so placed that the bottom is horizontal, and the blast plays on the large rectangular surface of metal. The converter is now so hot that the gas apparatus can be used.

By the hot-blast and oxygen addition the working at the end of the operation is extraordinarily hot. The loss is very slight, and amounts in the cupola and converter together to about 12 to 18 per cent. The operation lasts twenty to thirty minutes. The cast steel usually contains :—

	Per Cent.
Carbon	0·10 to 0·14
Silicon	0·18 ,, 0·20
Manganese	0·14 ,, 0·18
Sulphur	0·05 ,, 0·09
Phosphorus	0·04 ,, 0·08

R. M. Daelen * gives his experience of small Bessemer plant development during the last fifteen years. He instances the use of the Walrand-Delatte converter in Sweden, and considers this the only suitable converter for small plants. A furnace suitable for small open-hearth practice he considers to be the electric furnace, when cheap power is available. Crucible furnaces, made to tilt like a Bessemer converter, can be employed, the heat being developed by electrodes inserted in the refractory lining. This system has been successfully applied at the Kryptol Gesellschaft at Berlin.

Basic Bessemer Steelworks at Montigny.—L. Delacuvellerie † describes the new steelworks of the Société de Sambre-et-Moselle, at Montigny on Sambre. The plant comprises a basic steel equipment, rolling-mills, and a central electric station. The mills only run part time, but the remaining departments work continuously. The steelworks consists of three furnaces about 10 feet in diameter and 57 feet in height, each capable of producing 20 tons of molten metal per hour, and three converters, producing 15 tons of basic steel per blow. The greatest diameter of these converters is 10 feet, and their height 19 feet 6 inches. The furnaces and the converters are built above ground, in such a manner as to permit of free circulation for traffic, &c., beneath them. In the upper part of the converter-shop are fixed two travelling overhead bridges driven by electricity,

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* *Iron and Coal Trades Review*, vol. lxix. p. 1341.

† *Annales des Mines de Belgique*, vol. ix. pp. 560–563.

and each capable of lifting 25 tons. The bridges are fitted with four motors, controlling the various operations of which they are capable. The converters are worked by hydraulic power; the machinery being placed in a building next to the melting shop. The accumulator has a piston of 21½ inches diameter, 16 feet stroke, while the pressure of the water is 35 atmospheres.

The air required for the furnaces is supplied by a horizontal blowing-engine driven by steam, with two cylinders of 14¼ inches and 23⅜ inches respectively. The engine makes 40 revolutions per minute and was built by the Société Cockerill. The blowing-engine for the converters is a twin-cylinder compound machine, with two steam cylinders and two for air, placed tandem, behind those for steam. The smaller steam cylinder is 39½ inches in diameter, and the larger cylinder 70¾ inches, the wind cylinders having diameters of 59 inches. The number of strokes per minute is 30, and the air is blown at a pressure varying from 1½ to 2 atmospheres. This engine was also built by the Société Cockerill. At the end of the melting-shop and opposite the engine-shops is the casting-pit. The ingot moulds, holding about 2¼ tons of metal on an average, are placed in pairs on small flat bogies. A pair of hydraulic pistons work in the track, and by impinging on the ends of the bogies can propel the latter and their moulds in either direction. When the moulds have been filled, a locomotive takes the whole series to the mills. A small steam-hammer in one corner of the melting-shop serves for the sample tests of the steel.

With three blows hourly, and working twenty hours per day, the melting-shop can turn out 900 tons of steel daily. As a matter of fact, however, blowing only takes place during the day-time, and the daily output is about 400 tons. Adjoining the melting-shop is a dolomite shed, wherein refractory bricks and converter bottoms are made, but it possesses no special features. The mills and breakers in this shop, and the brick moulding and pressing machine are worked by means of an 85 horse-power electric-motor, and there is also an overhead traveller for handling the converter bottoms.

Steelworks in Hungary.—A description has been published * of the basic Bessemer works of the Rima Murany Salgo Tarjan Ironworks Company in Hungary. The plant comprises three 8-ton converters.

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* *Berg- und Hüttenmännische Zeitung*, vol. lxiii. pp. 277–278.

Steel in Japan.—C. E. Heurteau* describes the Wakamatsu Imperial Works in Kiushiu. The steelworks consists of two 10-ton Bessemer converters of the latest type, and there are two cupolas, besides a mixer of 160 tons, used when the two blast-furnaces are working together. There are also four Siemens furnaces of 22 to 23 tons capacity and a Wellman charging machine. The author also describes the mills and forges.

Basic Bessemer Slag.—In discussing the new steam method for the treatment of basic slag for agricultural purposes, it is pointed out† that the excellent results obtained seem to throw considerable doubt on the whole theory of citronic acid solution, as slag some 6 or 7 per cent. lower in soluble phosphoric acid contents produced by this steam method yields better results as a manure than the higher solubility slag meal produced by the ordinary method. Recently experiments have been made with a basic slag produced especially for the purpose without any addition of sand, and this fell into a fairly fine powder after only two hours' treatment at a steam pressure of only 8·5 atmospheres.

Combined Bessemer and Open-Hearth Process.—A combined Bessemer and open-hearth process, as proposed by H. W. Lash, consists in adding overblown Bessemer charges to a bath of cast iron in the open-hearth furnace. A plan of a proposed plant is given.‡

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* *Annales des Mines*, vol. vi. pp. 111–117.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 91.

‡ *Iron Trade Review*, June 9, 1904, p. 38.

FURTHER TREATMENT OF IRON AND STEEL.

Production of Sound Ingots.—An illustration is given * of an ingot treated by the Riemer top-heating process, and a number of analyses are given to show the chemical distribution in two ingots. Both show liquation or segregation of impurities close to the head.

Further details are given † of the Riemer method for the production of sound ingots. Photographs of sections of ingots, one cast in the ordinary way and another by that of Riemer, are given, the same ingot mould having been used for each. Both were cast from the same charge. The useless part of the treated ingot amounted to about 5 per cent. of the total weight, while that of the ingot cast in the customary manner amounted to more than 30 per cent. The influence which this method exerts on the chemical composition of the material has been further investigated and former investigations confirmed, the impurities being found to collect in that portion of the metal which had remained longest in the molten state, especially the carbon, sulphur, and phosphorus.

Casting Steel.—B. Osann ‡ deals with the origin and progress of the steel-casting industry, particularly of open-hearth casting, and subsequently with the exhibits at the Düsseldorf Exhibition. The moulds used have to be of fire-resisting material in view of the high temperature of the molten steel, and great difficulty exists in avoiding cracks when the moulds are dried and fired. Again this hard mould

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* *Iron and Coal Trades Review*, vol. lxviii. p. 1204.

† *Stahl und Eisen*, vol. xxiv. pp. 392–394, with three illustrations.

‡ *Ibid.*, pp. 650–655, 717–723, 776–782, with twenty-eight illustrations.

offers considerable resistance to the shrinkage of the casting if this should hang at any point, and such steel castings shrink about twice as much as those of ordinary cast iron. Apart from difficulties connected with the cracking of the mould another is due to the formation of hollows owing to the contraction of the metal. Those connecting with the outside are more liable to form if the metal is cast too hot, while on the other hand, if the metal is too cold when cast other hollows will form which are due to there not having been enough molten metal left to fill them. The author deals at length with the question of the contraction of the metal on casting and the troubles that it brings in its train. It is not possible to make thin steel castings in the same way as when cast iron is employed, probably owing to the changes which take place during solidification. An example is given of the casting of a thin pipe, which is easy in cast iron, while in steel the front and back of the metal will be found not to be adherent but separated from each other. Even a considerable head of molten metal will not suffice to prevent this, and if the steel is not very fluid the phenomenon is especially marked. Vertical casting is not very common in connection with steel, and molten steel entering at the top of the mould must not in any way meet with a contracted orifice, as a faulty casting is otherwise sure to result. It is customary to remove from the top a portion about half as long again as the width, and the author deals with the shape that this removed portion should possess. Various means are adopted to ensure a good surface to the casting, and with these the author deals. The casting is subsequently annealed. This is done not merely with a view to eliminate internal strains but also to improve the mechanical properties of the metal by altering its structure. The author quotes from former observations connected with the metal used in the construction of a large bridge showing that at most of the works annealing is effected at a temperature of 1000° to 1100° C.; subsequently allowing it to fall rapidly to 600° or 700°, and then keeping the metal at that temperature for some time. The furnaces employed are briefly mentioned. For small sections, undried moulds may be used, the author adding that in England this method is far more common than elsewhere, and that it is employed even for castings of greater side thickness. Only hydraulic moulding-machines are employed. The open-hearths used may have acid or basic linings, but the acid lining appears to have the advantage as the percentage of carbon is better under control.

The author then proceeds to describe the different kinds of steel castings and the metal employed. Thus a dynamo steel may contain—

Carbon.	Manganese.	Si+P+S.
0·10 to 0·15	0·2 to 0·3	0·2 to 0·4

the phosphorus and sulphur being present in very small percentages. This represents the softest kind of casting, with an elongation of 20 per cent. The next in softness would be used for worked machine parts of all kinds. It possesses an elongation of from 16 to 22 per cent., and would contain about—

Carbon.	Manganese.	Silicon.
0·25 to 0·30	0·3 to 0·5	0·3

Next come castings of harder metal used for various purposes such as grinding-mills, stone-breakers, &c. These would contain—

Carbon.	Manganese.
0·5 to 0·7	Up to 0·7

Occasionally the carbon may be as much as 1·1 per cent. Tungsten and chromium are also sometimes added when a very hard metal is desired. Krupp have added a still harder type of casting which is scarcely attacked by any kind of steel tool, while being at the same time so tough that it may be bent in the cold. Heating to redness takes away the hardness entirely, and the metal has therefore to be treated in the cold or by the aid, it may be, of the electric welding machine. The use of this material is therefore very limited. The composition of the metal is a trade secret. Krupp also made a so-called "special" steel for ordnance. This is a nickel steel. Manganese steel is referred to, while the Huth method for centrifugal casting is also mentioned. This enables an exterior of hard steel to be cast with a layer of softer and tougher metal inside it.

B. Osann * also describes the steel castings of various kinds that were exhibited at the late Düsseldorf Exhibition.

Use of Thermite.—The method of mending a long crack in a plate with the aid of thermite is described.†

Electric Welding.—W. Meng ‡ describes the electric welding of the low-pressure cylinder of a 1000 horse-power steam-engine at the

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* *Stahl und Eisen*, vol. xxiv. pp. 776–782, 836–844, 892–905, with 101 illustrations.

† *Iron Trade Review*, April 14, 1904, p. 35.

‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. p. 1263.

Oskraft works. The cylinder was 1250 millimetres in internal diameter. On January 13, 1904, a crack, 700 millimetres in length, was detected, and this was put in order by the Slavianoff welding process. On cooling, a second crack, 530 millimetres in length, developed, and on heating this the orginal weld broke afresh as the welding extended through half the thickness only. The two cracks were then treated to the full thickness of 40 millimetres, and were welded in 12 sections within 4½ hours in the same heat on March 4, 1904. The mend was perfect. The total cost was £45 to £50, whilst a new cylinder would have cost £350 to £400, and the engine would have been at least three months longer out of use.

High-Speed Tool Steels.—L. Demozay * details the considerations which should influence the choice of steel for high-speed cutting. He gives a number of formulæ, involving price, speed of cutting, and weight of metal removed, which should aid in the selection of the best material, and includes the factors of time, power required, &c., giving a number of tables embodying the results of careful experiments. He dwells on the shape and size of the pieces removed, in relation to the efficiency of the tool, and the correctness, stability, and accuracy of its set, pointing out how much depends upon these considerations, and particularly upon the latter. The rationale of cutting is described and figured. He discusses the treatment of the tools, which he thinks should be largely in the hands of the manufacturers of the tools employed—indeed, he advocates the tools being supplied ready made, as a safeguard to the interests both of the manufacturers and their customers. The shape is also dealt with, and the right set to be employed is strongly emphasised. After dealing briefly with the measures to be taken to guard against evil results arising from the extreme brittleness peculiar to certain descriptions of high-speed tool steels, he examines in detail the question of the relation which should exist between speed of cut, and the nature of the material being worked, together with considerations as to its shape, size, &c.

H. Eckardt † observes that high-speed tool steel is not now merely of much importance, but is of absolute necessity in works, machine shops, and shipbuilding yards. It is not, however, he thinks, the Taylor-White steel which has achieved this foremost position, and

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* *Revue de Métallurgie*, 1904, pp. 361–389, with twelve illustrations.

† *Stahl und Eisen*, vol. xxiv. pp. 611–613, with five illustrations.

he believes that other steels which European firms have attempted to introduce have failed in a similar way. This has been due chiefly to the secret trade methods of hardening to which these steels had to be submitted. It was too great an annoyance for large works to keep sending back the worn tool each time it wanted re-treating to the works from which it came. Another reason why these tools found no lasting use was probably due to their being easily broken. They were in part so brittle that the steel often fractured even when it was being put into position if the least bend was at all possible. It was soon seen, therefore, that any metal that needed hardening in this secret manner was useless for practical purposes, even though the tool made from this metal was of exceptional cutting quality, and further, that the Taylor-White method, which in addition to secret hardening also necessitates certain definite shapes for the cutting parts, and consequently a special method of operation was of little general value. It was evident that what was needed was a steel of excellent quality, for the special purpose to which it was to be put, and one that the works using the tools made from it could themselves manipulate. Most works soon succeeded in making such steels by the addition of considerable percentages of tungsten and chromium. Such a steel could be readily worked up and hardened very easily in the air or in an air current. After annealing it was found that it could be worked in the cold. This last property considerably widened its scope of usefulness. Almost all crucible steel works took up the manufacture of this metal, and great competition ensued. This necessitated in turn each works paying the greatest attention to improving the quality of its product. Up to recently, however, existing machines were unable fully to utilise these new steels. The result was that the machines themselves had to be improved until they fulfilled the new requirements, and the author now describes one of these designed by Otto Froriep. The author further discusses the actual way in which these rapid-cutting tool steels act, and he shows that the greater resistance the tool shows to the wearing away of its surface by the turnings produced the longer will be its life as a cutting tool.

A. D. Wilt * describes the introduction of high-speed steel into a factory.

Heat Treatment.—J. Windle † advocates thermal treatment for tires, especially when they are made of high carbon steel, and thinks

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* *Engineering Magazine*, vol. xxvii. pp. 913–920.

† *Engineer*, vol. xcvii. p. 545.

that the work will not be undone by heating the tires when they are shrunk on. Some tests are given and receive favourable comments from T. Vaughan Hughes.[*]

J. E. Stead[†] deals with the unexplained fracture of two shell plates of a Scotch type marine boiler in Canada, and to the criticisms raised with reference to the researches carried out by himself and A. W. Richards, on the heat treatment of crystalline steel. He points out that in the vast majority of so-called mysterious failure investigation can trace the occurrence to some slight initial flaw, and defends the statements that heat treatment can restore steel which, by injudicious heating, has developed a dangerous crystallisation.

Composition of Quenching Baths.—H. Le Chatelier[‡] gives the composition of a number of baths for quenching and tempering. Fused nitrates of potassium and of sodium are too high in temperature for certain cutting tools, as they do not permit of cooling below 220°. Mixtures of nitrate of potassium and of nitrate of sodium can, however, be employed, and a series of mixtures fusing at different temperatures be obtained. He gives the following proportions for these mixtures:—

Temperature.	Nitrate of Potassium.	Nitrate of Sodium.
280°	0	100
230°	20	80
172°	40	60
145°	50	50
137°	55	45
145°	60	40
225°	80	20
335°	100	0

Higher temperatures than 400° cannot be obtained with these mixtures. At 400° potassium nitrate freely decomposes, whereas in steels where, without extreme hardness, absolute absence of brittleness is necessary, 500° to 600° are temperatures more suitable. The following bath gives, on fusion, a temperature of 500°:—

	Parts.		Parts.
Sodium chloride . . .	1	Fused calcium chloride . .	2
Potassium chloride . . .	1	Hydrated barium chloride . .	1

Hydrate stronium chloride . . 3 parts.

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[*] *Engineer*, vol. xcvii. p. 569.

[†] *Ibid.*, vol. xcviii. p. 305.

[‡] *Revue de Metallurgie*, 1904, pp. 303–304.

For a bath fusing at 700° the following mixture may be used:—

Hydrated boric acid crystals	1	part.
Silver sand	1½	„
Anhydrous potassium carbonate	1	„
„ sodium carbonate	1	„

When prolonged treatment is required a little cyanide or charcoal may be added to prevent superficial decarburisation, but, in view of the strongly cementating action of cyanide this salt must be used with caution.

Small Annealing Furnace for Steel Castings.—Illustrations are published[*] of a small annealing furnace for steel castings used in connection with small Bessemer converters. The firebridge is placed beneath the hearth, the products of combustion pass beneath and around the hearth and enter at the back, playing around the castings to be annealed on their way to the escape outlets placed at the other end of the furnace. In this way they tend to keep away any air that might enter through cracks at the charging door.

The Manufacture of Tubes.—M. Halstead[†] gives some information, from an American point of view, on the manufacture of tubes in England, and especially describes Inshaw's process. In this method, puddled balls are rolled into slabs, nicked, bent round, and welded into a hollow bloom of hexagonal or circular cross-section.

An illustrated account has been given[‡] of the tube-making machinery at the Niclausse boiler works of Willans and Robinson at Queensferry, near Chester. The steel used is made in one 20-ton and one 50-cwt. open-hearth furnace. Billets 3½ inches square and 26 inches long are punched hot, and are then drawn into tubes 7 feet long and 3 inches in diameter, with frequent annealings.

Structural Ironwork.—The method of construction employed in connection with the steel structure of the great Flat-iron Building, New York, is described by Frahm.[§] The building is about 270 feet in height.

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[*] *Stahl und Eisen*, vol. xxiv. p. 658.

[†] *Iron Trade Review*, July 14, 1904, pp. 49–50.

[‡] *Engineer*, vol. xcviii. pp. 7–10.

[§] *Stahl und Eisen*, vol. xxiv. pp. 456–457, with three illustrations.

The Manufacture of Armour Plates.—A. Bizot[*] describes the manufacture of armour plates at the Forges de la Chaussade, France. New steelworks with two open-hearth furnaces of 12 and 18 tons have been installed. Nickel-chromium steel plates are amongst the various kinds of armour plates made.

Tin Plate.—A plan is given[†] of a tin plate works at Steubenville, Ohio. The bars used are of open-hearth steel, and are delivered in long lengths. The hot mills have 12 stands of 26 by 32 inch rolls. Each mill has its own squaring shear, and all shearing is done in the day. The mill building is 80 by 420 feet, the opening floor 40 by 400 feet, the annealing house 75 by 360 feet, and the tinning house is 70 by 300 feet in area. The latter contains 16 duplex tinning sets.

The smelting of tin in shaft furnaces is described by A. af Forselles.[‡]

Galvanising.—Iron and other articles can be coated with zinc by first cleaning them thoroughly, and then heating them in a closed receptacle in the presence of zinc dust. The temperature required is 500° to 600° F., which is about 200° F. below the melting point of zinc, but all the same a thin coherent coating is formed. The iron must be free from rust, but the presence of grease does not stop the process. The process is known as sherardising.[§] It is described, with the aid of a number of illustrations, by Sherard Cowper-Coles,[||] and some tensile tests of the raw and treated material are given to show that the properties are not affected.

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[*] *Génie Civil*, vol. xlv. pp. 193–197.

[†] *Iron Age*, May 5, 1904, pp. 30–31.

[‡] *Teknikern* (*Helsingfors*), vol. xiv. pp. 245–248.

[§] *Engineer*, vol. xcvii. p. 606.

[||] *Engineering Review*, vol. xi. pp. 101–108; *Electro-Chemist and Metallurgist*, vol. iii. pp. 828–836; *Iron and Steel Magazine*, vol. viii. pp. 333–342.

PHYSICAL PROPERTIES.

Properties of Iron at Liquid Air Temperatures.—R. A. Hadfield * discusses the extraordinary effect upon pure iron of extreme cold, namely, 180°. The tensile strength rises to 54 tons, the ductility disappearing altogether. He was, however, unable to discover any structural change due to the temperature. One specimen of an alloy containing 24 per cent. of nickel, 5 per cent. to 6 per cent. of manganese, and the rest iron, had an elongation at low temperature of about 6 per cent., whilst the tenacity increased about 10 per cent. In nickel there was no diminution of elongation under low temperature. Specimens photographed at low temperature were polished and etched under ordinary temperature. The author added later that the difference in the degree of ductility might be due to the speed at which the load was applied, and by proper manipulation a ductility approaching that of ordinary temperatures might be obtained.

Hardness of Metals.—G. T. Beilby † discusses the hard and soft states in metals, and advances various views based on his earlier observations of surface flow. It is suggested that the two states are perfectly distinct phases, and that the hard phase is amorphous, and the soft state is crystalline. The hard phase is produced by mechanical working, and return to the soft phase is effected by heat.

A. Ohnstein ‡ observes that the Brinell method for the determination of the hardness of a steel rail consists in determining the extent of the depression in its face effected by a hard steel ball under a given pressure. The Huber apparatus for this test is now described. It is small and compact, and represents a very simple form of hydraulic press, by the aid of which a pressure of about a hundred tons may be exerted on the ball.

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* Paper read before the British Association, August 1904: *Engineering*, vol. lxxviii. p. 308.

† *Electro-Chemist and Metallurgist*, vol. iii. pp. 806–826.

‡ *Stahl und Eisen*, vol. xxiv. pp. 399–400, with one illustration.

Criticisms are published* of the Huber apparatus for testing, the Dübelwerke Company maintaining that this apparatus is but a colourable imitation of their own apparatus.

This apparatus is also discussed by Witte,† who points out that the simplest way of exerting great pressure is by means of an explosion. This has also the advantage that the nature of an explosion being sudden, there is no need to firmly fix the testing apparatus to the test-piece. Various methods exist for measuring the strength of an explosion. The author would perform this test in the following manner: a hardened steel ball is placed upon the material to be tested, and on this a steel cylinder working in a steel pipe used as a guide. On this cylinder a cartridge of known strength is placed, some shattering explosive such as dynamite or gelatine dynamite being employed. This cartridge being exploded on the surface of the cylinder, forces it downwards, and so causes the steel ball to be driven into the surface of the material under test, the extent of the resulting depression being a measure of the hardness of the material.

An apparatus for making indentation tests on steel is described by Guillery,‡ the principle involved being that of the depth of penetration of balls pressed statically upon the sample the hardness of which is under investigation. The ball is pressed against the surface by means of Belleville discs dished to a known degree. The apparatus is calibrated against metals of known hardness, and the diameters of the imprints are gauged by an appliance devised by H. Le Chatelier, which gives readings correct to one-tenth of a millimetre, visible to the naked eye.

Fatigue in Metals.—A. N. Kemp§ deals generally with the subject of fatigue in metals, describing Wöhler's experiments and deductions in some detail, and then giving a résumé of the results of other experimenters on various forms of repeated stress. The formulæ of Launhardt, Weyrauch, and Unwin are given.

C. S. Palmer describes the appearance of the fracture of some tie-rods from a reverberatory furnace, and discusses its cause as due to crystallisation and fatigue.

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* *Stahl und Eisen*, vol. xxiv. pp. 647–648.

† *Ibid.*, pp. 648–649.

‡ *Engineer*, vol. xcviii. p. 426.

§ *Engineering Review*, vol. xi. pp. 168–178.

Effect of Rapid Alternating Stresses.—J. O. Arnold [*] contributed a paper on this subject, pointing out that steels possessing similar chemical composition give astonishingly different mechanical results. To a considerable extent, however, the microscope fails to reveal the cause of these discrepancies.

Crushing as a Method of Testing.—Denis [†] points out the value of crushing tests as applied to determine the strength of castings, and describes a method of carrying out the operation.

Resistance to Impact.—A. Perot [‡] describes a method of investigating the results of impact tests upon metals. He points out the discordance that is found to exist between resistance to breaking strain and the amount of shock required to cause fracture. He therefore determined to investigate the actual force applied to the test bars at various periods during the impact, the experiments being principally conducted upon notched bars.

Maximum Momentary Pressure resulting from Sudden Impact.—C. Frémont [§] briefly reviews, in historic sequence, the experiments which have, from time to time, been made to determine pressure on impact. In 1695 P. de Lahire published some observations, and further researches were made at Leyden, in 1720, by Gravesande, a Dutch physicist. He quotes de Camus, who pointed out, in 1722, the inadequacy of the methods then in vogue, which were to drop a weight, attached to a cord, from a height sufficient to cause rupture, and determine, by means of a similar cord, the actual breaking strain, by means of slowly increased loads, those effecting rupture being regarded as the index of the force exerted in the parallel experiments with the falling body. De Camus himself preferred to investigate the deformations produced by falling bodies upon discs of lead, thus following the steps of Leonardo da Vinci, who had used crushing forces as far back as the fifteenth century. The author then passes to a brief consideration of recent work, and points out that although certain methods give concordant results, a slight variation in the method renders the results

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[*] Paper read before the British Association, August 1904; *Engineering*, vol. lxxviii. p. 307.

[†] *Revue de Métallurgie*, 1904, pp. 292–300, with seven illustrations.

[‡] *Ibid.*, pp. 287–291, with eight illustrations.

[§] *Ibid.*, pp. 317–333, with sixteen illustrations.

entirely untrustworthy. Indeed, most published results only apply to the conditions under which the tests were applied, and are of little or no value under other conditions. His own method resembles that used by de Manplow. This consists essentially in taking a leaden cylinder, and subjecting it to a gradually applied crushing stress in a specially contrived press. Both the degree of deformation and the amount of energy actually expended in effecting it can thus be accurately known. A second cylinder, resembling the first in dimensions and materials, is now subjected to the sudden impact of a falling weight. This produces a definite degree of deformation, and the cylinder, now somewhat flattened and deformed, is put into the press, and stress is applied until the amount of the resulting deformation is equal to that of the first cylinder. The difference between the energy expended on the two occasions is taken to be a measure of the work done by the falling weight; in other words, the amount of force required to produce a definite degree of deformation in the second case of the impacted cylinder, deducted from the amount required to produce the same deformation in the original cylinder will give, it is assumed, the energy of instantaneous impact. Allowance will, of course, have to be made for a few secondary results, heating, friction, &c., but the results are a sufficiently close approximation to the truth, to be of use in practice. He then passes to the consideration of the kinetic energy of impact in elastic bodies. Taking, as an illustration, the coupling-hooks of a railway waggon, he shows that, although never subjected to the full maximum stress which they can withstand, failures and breakages are frequent. This is owing to the engineers and designers having failed to provide for the accumulated results of a long series of shocks, although ample margin as against the maximum single shock likely to be met with, may have been provided. The use of springs for absorbing and neutralising the surplus energy of shock is dealt with, and finally certain practical conclusions are enumerated, which should influence the size and dimensions of such portions of machinery as are constantly subject to sudden impact stresses.

Stresses in Thin Cylinders.—A. T. Weston * deals with the problem of the investigation of stresses in thin cylinders, subjected to internal pressure. The method employed gives results which, it is claimed, are more direct and practical than the usual mode in which such stresses are investigated. Diagrams are given, and the

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* *Engineer*, vol. xcviii. p. 298.

results have, the author considers, an important bearing upon the behaviour of cylinders, of non-circular section, built of riveted plate, and subjected to internal pressure.

Metallography.—The evolution and aim of microscopic metallography are discussed by G. Cartaud.*

H. Le Chatelier † contributes a note designed to modify certain statements made in an earlier contribution ‡ where he had described the relative occurrence of austenite and martensite.

W. Campbell § deals with the relation of microstructure to the rate of cooling in steel, in white cast iron, and in other metals, basing his observations on Roozeboom's diagram.

A description has been published ‖ of the metallography department of the Royal Testing Institution at Gross-Lichterfelde-West.

F. Osmond ¶ and C. Frémont point out in continuation of their work with G. Cartaud ** that, inasmuch as iron and soft steels each possess two distinct systems of structure, the cellular and the crystalline, and that each of these structures undergoes characteristic modes of deformation and rupture, the ultimate fracture of samples must be studied from the point of view of the combined effect of these two unknown quantities. It might be thought that there might exist between these two unknown factors certain definite relations which might have led to their indirect recognition, and indeed, for some time, this was believed to be the case, but recent researches by A. Considère and A. Le Chatelier have disproved the existence of any such relation. Two steels yielding the same results on tensile tests, the same resistance, the same elongation, and the same contraction, may, under different stresses, behave quite differently. Thus it may happen that samples which have satisfactorily withstood all the usual tensile tests fracture simply in falling to the ground. Static tests, amongst which technological requirements have led to tensile tests obtaining a preponderating proportion, principally bring into play, and hence serve to measure, cellular deformation. To attack the

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* *La Revue Technique*, vol. xxv. No. 5.

† *Revue de Métallurgie*, 1904, pp. 301–302.

‡ *Ibid.*, p. 222.

§ Paper read before the Philadelphia Foundrymen's Association, April 6, 1904; *Iron Age*, April 21, 1904, pp. 23–26.

‖ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. p. 1149.

¶ *Revue de Métallurgie*, 1904, pp. 199–207.

** *Ibid.*, pp. 11–45.

problem as regards crystalline structure, the latter must be isolated from the cellular structure which masks it, and the method resolves itself into either preventing or confining to certain limits, the local production of the more considerable degrees of deformation, which are cellular in nature.

Three methods fulfil these conditions. They are (1) that of traction tests by shock, from a suspended wire. In proportion as the height of fall of the weight is increased, the elastic limit rises, approximating to the breaking strain until it coincides therewith; at the same time the elongation diminishes to zero, and fracture takes place with the minimum absorption of kinetic energy. (2) Another method is by small bending tests in alternating directions, frequently repeated, which was due to Wöhler, and is already old, although not even now correctly understood, the idea having prevailed that every piece of metal must ultimately break after continuous alternative bending, and that although these may be very numerous, they are not infinite, even when in no single instance has the limit of elasticity been reached, so long as the maximum charge upon the most fatigued fibre is not too far below this elastic limit. It was not suspected that the elastic limit might be, in local instances, reached under stresses greatly below the true elastic limit per unit section of the whole piece. It is these local deformations which cause the final rupture, hence, in applying bending tests, it is necessary to resort to compression by tightening up a portion of the piece to avoid these local deformations. (3) The last method, bending by successive impacts of notched or hammered bars, has been more particularly studied by A. Considère and A. Le Chatelier. Here the conditions at the surface of the bar being altered by hammering, or more thoroughly by notching, hinder or prevent the greater tensional deformations of a cellular nature, and favour those of a crystalline nature if the latter have a tendency to be produced.

None of these methods, however interesting as researches, are of much practical value, as they do not deal with the metal under such circumstances as generally arise in practice. From this point of view Wöhler's is the best. It may be seen, however, that the methods suitable for measuring the crystalline deformations are precisely those proposed to determine brittleness. In these circumstances, the brittleness of a sample acquires a fresh significance as the limit of crystalline deformations. Two tests are therefore required, a static test and a brittleness test, from which the unknown factors may be deduced. The authors detail the experiments undertaken with this object in view, and the conclusions at which they arrived.

Magnetic Properties of Iron.—W. M. Mordey[*] and A. G. Hansard deal with energy losses in magnetising iron, and the results of tests are given and discussed.

E. P. Harrison[†] describes experiments on the variation and temperature of the magnetic permeability of nickel and iron.

A. Gray[‡] and A. Wood deal with the effect of a magnetic field on the rate of subsidence of torsional oscillations in wires of nickel and iron, and the changes produced by drawing and annealing.

C. E. Skinner[§] deals with the commercial testing of sheet steel for electric purposes, and reviews the chemical tests to determine the losses in the steel before punching, before and after annealing, the loss due to ageing or to moderate increases in temperature, and permeability tests.

Allotropic Transformations of Nickel Steels.—O. Boudouard[‖] describes a method suggested by Saladin, for determining the critical points of nickel steel, which can be adapted to industrial requirements. The method is based on the variation of the electric resistance which occurs in such steels at different temperatures. The apparatus is as follows: the bars of metal employed are 10 centimetres long and 1 centimetre in diameter, and are pierced through the middle by a hole 5 millimetres in diameter for the insertion of the thermo-electric couple. At each end of the bar a saw cut is made, into which a platinum wire is forced, being bound by a piece of iron wire. The two platinum wires, suitably insulated, are placed in connection with a delicate galvanometer. The whole contrivance is placed inside a porcelain tube, which can be heated in an electric furnace to 1200° C. in an hour and a half. Saladin's method entails two thermo-couples, one to give the temperatures of the metal under observation and the other the differences between these temperatures and that of another sample not undergoing transformations at the

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[*] Paper read before the British Association, Cambridge Meeting, 1904.

[†] *Philosophical Magazine*, 1904, pp. 179–205.

[‡] *Proceedings of the Royal Society*, vol. lxxiii. pp. 286–291.

[§] Paper read before the American Society for Testing Materials, June 1904; *Iron Age*, June 23, 1904, pp. 4–6.

[‖] *Revue de Métallurgie*, 1904, pp. 80–88.

temperatures of the experiment. A series of curves are given showing the results obtained in practice, and these results are compared in a table appended.

H. Le Chatelier * also describes the method employed by Saladin for the registration of critical points.

Hardening of Steel.—In a paper read before the German Bunsen Society E. Heyn † discussed the hardening of steel from the physical-chemical standpoint.

The theory of hardening is also discussed by P. Rohland.‡

Brittleness of Steel.—A pendulum impact apparatus for testing steel for brittleness used at Willans and Robinson's works at Rugby is described by E. G. Izod.§ Notched test-pieces are used.

P. Fain ‖ contributes an account, with diagrams, of a series of trials of thin notched bars, under a variety of conditions.

Special Iron Alloys.—J. Ohly ¶ continues his review of the special iron alloys used in steel-making, and deals with those alloys containing titanium, vanadium, boron, uranium, aluminium, and silicon.

W. Metcalf ** briefly reviews various alloy steels, especially high-speed tool steels, giving the following analyses of the latter:—

Mo.	W.	Cr.	C.	P.	S.	Si.	Mn.
...	9·99	2·83	0·69	0·010	0·010	trace	trace
...	18·48	2·90	0·78	...	...	...	0·33
9·65	...	...	0·66	0·016	...	0·046	0·22

Some discussion is progressing in the United States on the Customs duties to be levied on ferro-chrome as compared with those on the other ferro-alloys.††

Manganese Steel.—Further researches on manganese steels are given by L. Guillet, ‡‡ showing how the presence of troostite and of

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* *Revue de Métallurgie*, 1904, pp. 134–140, with seven illustrations.

† *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 317.

‡ *Chemiker Zeitung*, vol. xxviii. p. 569.

§ *Report of the Seventy-third Meeting of the British Association*, London, 1904, p. 787.

‖ *Revue de Métallurgie*, 1904, pp. 305–316.

¶ *Mines and Minerals*, vol. xxv. pp. 44–45; compare *Journal of the Iron and Steel Institute*, 1904, No. I. p. 656.

** Paper read before the American Society for Testing Materials, June 1904; *Iron Age*, June 23, 1904, pp. 8–9.

†† *Iron Age*, June 16, 1904, pp. 12–13; June 23, 1904, p. 15.

‡‡ *Revue de Métallurgie*, 1904, pp. 89–91.

martensite complicate the problems involved. He concludes that these steels cannot be used without quenching, as the hardness of the troostite-martensite structure is insufficient for the purposes to which manganese steel is usually applied.

Tungsten Steel.—L. Guillet* has investigated steel made at Imphy, which can be divided into two series, the first containing from 0·11 to 0·27 per cent. of carbon, and the second 0·65 to 0·867 per cent. of carbon, with varying amounts of tungsten in both series. He points out that the micrography of tungsten steels is comparatively simple, and that all the attacks were made by the aid of picric acid, except in one instance, when a soda solution of sodium-picrate was employed. With the first series it was found that, with from 0·0 to 10·0 per cent. of tungsten, the steels possessed the same constituents as ordinary carbon steels, except that the pearlite is less pronounced, and that even under low powers the alternating flakes of ferrite and of cementite are clearly distinguishable. At 10·0 per cent. numerous specks, too small to be photographed, appear. It is this constituent which is met with in all other specimens, up to 40·0 per cent. of tungsten. Hence these steels can be divided into two groups.

In the second series the resemblance to ordinary steel is maintained up to 5·0 per cent. of tungsten, the proviso as to pearlite likewise obtaining. After 5·0 per cent. the white specks become manifest, but assume the appearance of numerous elongated filaments, the form and size depending very largely upon the mechanical treatment the steel has undergone. All steels containing over 5·0 per cent. of tungsten enclose this constituent. In a steel with 35·0 per cent., a large crystal, surrounded with numerous small ones, was discovered.

In this series the classification can be made as follows—

First class.—From 0·0 to 5·0 per cent. of tungsten; constitution resembling ordinary carbon steels.

Second class.—Steels having over 5·0 per cent. of tungsten; enclosing the special constituent.

The special constituent appears to be a carbide. It closely approximates, in certain characters, to cementite. Thus it is revealed by polishing in bas-relief, and stained black by a sodium solution of sodium picrate. Tests similar to those made in the case of chrome

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* *Revue de Métallurgie*, 1904, pp. 263–288, with twenty-two illustrations.

steel were continued with the tungsten steels, to investigate their more purely mechanical properties. The results and the diagrams elucidating them are given. The following conclusions were arrived at: tungsten steels can be divided into two fairly distinct groups—pearlite steels and steels containing the double carbide. The first group presents characters comparable with those of ordinary carbon steels, except that, for a given carbide percentage, the breaking strain, elastic limit, and brittleness are higher, and the elongation, contraction, and stability under impact lower the larger the proportion of tungsten they contain. The difference that exists in the mechanical properties of an ordinary carbon steel and a tungsten steel of the same percentage is at times most marked. The pearlitic steels are strongly affected by quenching in the same manner, but to a much greater extent than carbon steels. Reheating softens them.

Steels containing the double carbide vary in their properties according to their carbon contents. Speaking generally, their breaking strain and elastic limit are distinctly lower than those of the pearlite group containing similar amounts of carbon. Their brittleness is medium, and their resistance is considerable, whatever their carbon or tungsten percentage. Quenching at 850° transforms them, with the development of an exceedingly fine martensite structure, and the separation, provided the tungsten percentage is sufficiently high, of a portion of the carbide. After quenching the strength of the steel is markedly improved.

Chrome Steel.—L. Guillet * gives an account of his investigations carried out on samples made at the Imphy Works. Analyses are given showing that the amount of chromium present ranged from just over 0·50 per cent. to 36·34 per cent. of chromium, and these details are accompanied by a series of photomicrographs of the steels under examination. For etching steels with less than 9 per cent. of chromium, picric acid was used, while for steel containing a higher percentage either bisulphate of potassium or hydrochloric acid was employed. He finds that the constitution of steels containing up to 7·0 per cent. of chromium is the same as that of ordinary carbon steels. The grains of ferrite, however, become smaller and smaller as the amount of chromium increases, showing that, as Osmond pointed out, the presence of chromium hinders crystallisation. Above

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* *Revue de Métallurgie*, 1904, pp. 155–183, with thirty-six illustrations.

7·0 per cent. and up to 13·6 per cent. of chromium the structure is martensite. At the higher percentage ill-defined polyhedrons, bordered with minute white grains, appear, which, etched with bisulphate, reveal a very fine martensite structure, while the minute brilliant white grains are a double carbide of iron and chromium. Increasing the percentage of chromium causes the white grains to become much more numerous, until the martensite structure finally disappears. On reaching 25 per cent. of chromium, these white grains commence to form masses and to invade the interior of the polyhedrons. The appearances are considerably influenced by the method of preparing the samples and by the temperature of the rolling which the steel has undergone. For the first series of steels examined he summarised the results as follows:—

Steels containing 0·0 to 7·0 per cent. of chromium; structure resembling those of carbon steels.

Steels containing 7 to 20·0 per cent. of chromium; martensite structure.

Steels containing over 20·0 per cent. of chromium; enclosing a constituent peculiar to chrome steels.

The second group can be further divided into three categories:—

(1) From 7·0 to 8·0 per cent.; *a* iron and martensite.

(2) From 10·0 to 13·0 per cent.; pure martensite.

(3) From 13·0 to 20·0 per cent.; martensite and the special constituent.

In the second series, steels containing 5·0 per cent. of carbon and less, the structure is similar to that of chrome steels, except that the pearlite more closely resembles that of manganese steels, *i.e.*, is more compact than in chrome steel. A steel with 7·0 per cent. of chromium resembles a manganese steel with 0·80 per cent. of carbon and 5·0 of manganese. That is to say, it presents a reniform structure easily tinted by either picric or nitric acids, and closely resembling troostite. Indeed, it should be actually regarded as troostite. The subdivisions of the second series of steels (carbon, 0·0 to 5·0) are as follows:—

Steels containing 5·0 per cent. of chrome or less; structure resembling ordinary carbon steel.

Steels containing 6·0 to 18·0 per cent. of chromium; martensite structure with reniform granules of troostite.

Steels containing over 18 per cent. of chromium; structure similar to that already noted in the case of low carbon steels (special constituent).

The second division is again capable of three subdivisions, viz.:—

(1) α-iron and martensite.

(2) Martensite and troostite.

(3) Martensite, troostite, and the double carbide of iron and chromium.

As to the latter, the author points out that in ferro-chromes containing 57·0 to 59·0 per cent. of chromium a double carbide closely agreeing with the formula $Fe_3C\ 3Cr_3\ C_2$ has been already isolated, while the existence of the carbide $Cr_3\ C_2$ cannot be contested. In low chrome steels (2 per cent.) Carnot and Goutal isolated a carbide $2Fe_3C$, Cr_5C_2, and Williams obtained in the electric furnace several double carbides: $3Fe_3C$, $2Cr_3C_2$; and $2Fe_3C$, $3Cr_3C_2$. The author hopes to fix definitely the composition of the special constituent before long. That it is a carbide has been proved by cementation experiments described subsequently.

The mechanical tests applied were tensile tests, impact, and hardness. The results were:—

(1) Steels containing 0·0 to 7·0 per cent. of chromium; similar to ordinary carbon steels, except that the breaking strain rises with the percentage of chromium present.

(2) Steels containing 7·0 to 22·0 per cent. of chromium; breaking strain and elastic limits very high, elongation and contraction low.

(3) Steels containing over 20·0 per cent. of chromium; breaking strain medium, elastic limit relatively low, elongation and contraction relatively high.

The shock tests made by Frémont's method and the hardness test (Brinell) confirm the division into three classes, the 7·0 per cent. and under samples being hard and resisting impact, those with 7·0 per cent. to 22 per cent. of chromium yielding medium results in both cases, and those containing more than 22 per cent. of chromium being highly brittle. The third class of results combined with the tensile tests previously described show once again that, with high percentages of chromium, the samples, notwithstanding their brittleness, give high elongation and contraction results.

With steels of the second series only two classes can be distinguished—

(1) Very hard steels containing up to 18·6 per cent. of chromium.

(2) Medium hard steels containing over this percentage of chromium.

A further series of investigations relating to quenched steels is given, accompanied by photomicrographs of the results obtained, the researches following the sequence of those already detailed. The steels were quenched from 850° to 20° in one series and from 1200° to 20° in a second series. The author then passes to the consideration of annealed steels, the temperature of annealing having been from 900° to 1200°, and the period invariably four hours, and finally discusses the question of cement steels. His general conclusions are as follows:—

Chrome steels can be grouped into four classes—

(1) Pearlitic steels; breaking strain, elastic limit, and hardness greater in proportion to the increase in chromium percentage, elongation and contraction high, resistance to impact dependent upon amount of carbon present. These steels undergo considerable change in their mechanical properties by quenching from 800°, and this corresponds to the changes of ordinary carbon steels. But with low carbon steels the breaking strain and elastic limit increases, and the elongation and contraction diminish much more rapidly without chromium than with it.

(2) Martensite or troostite steels; breaking strain, elastic limit, and hardness high, elongation and contraction low, brittleness varying with the percentage of carbon. These steels are slowly softened down by reheating and tempering.

(3) Steels containing the double carbide; breaking strain and elastic limit somewhat low, elongation and contraction fairly high, brittleness extreme. These steels are softened by tempering at 850°, and more strongly still at 1200°, when the double carbide partly disappears. Reheating produces the same effects. The author promises, when he has accumulated sufficient data, to assemble the results in curves, as he has previously done in the case of nickel and manganese steels.

L. Guillet * describes elsewhere the preparation, structure, physical and chemical properties of chrome steel.

Silicon Steel.—L. Guillet † details the results of a series of experiments on silicon steels. The conclusions at which he arrives are that no more than 5 per cent. of silicon is admissible. In particular it was found that the non-brittleness of these steels, when quenched, was very considerable. One of the diagrams given sums up the constitution of the steels, as regards which, only one point, that of

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* *Génie Civil*, vol. xliv. pp. 281–284, 298–300.

† *Revue de Métallurgie*, 1904, pp. 46–67, with twenty-eight illustrations.

samples containing from 7 to 20 per cent. of silicon, still remains doubtful. The samples examined were principally of a solution of silicon in iron, whereas commercial samples of ferro-silicon containing about 12 per cent. of silicon consist largely of silicide of iron, Fe_2Si. The author believes he has found an explanation of the white patches that are found in certain crude silicon steels, and become developed in others on annealing and tempering.

Molybdenum Steel.—L. Guillet[*] has investigated the properties of molybdenum steels, and finds that they approximate closely to those of other steel alloys. The steels were made, as in previous instances, at Imphy, and were found to present two distinct groups, the first containing from 0·0 to 10·0 per cent. of molybdenum with 0·188 to 0·489 per cent. of carbon, and the second 0·50 to 14·64 per cent. of molybdenum and 0·735 to 0·824 of carbon. The general conclusions respecting these steels, based, as were the earlier investigations relating to silicon, chrome, and tungsten steels, on the microstructure, and the tensile strength of ordinary and of quenched samples were as follows:—

The first group is pearlitic, the second contains a double carbide. Steels of the latter group, quenched from 850°, reveal a martensite structure, with some undissolved carbide, the amount of the latter corresponding with the percentage of molybdenum. In nearly every respect alloys of molybdenum closely resemble tungsten steels.

L. Camprédon[†] gives details of the influence of molybdenum on steel. The action is similar to that of tungsten but more energetic.

Vanadium Steel.—L. Guillet[‡] has investigated the influence of vanadium on steel. Two sets of test pieces were made, one containing 0·2 of carbon and the other 0·80. In each series the vanadium varied between 0·0 and 10 per cent., special attention being devoted to the specimens with from 0 to 3·0 per cent. of vanadium. The results showed that three kinds of useful steels resulted, and that no steel with more than 7·0 per cent. of vanadium is of any technical use, the brittleness then being too great. The first set of 0·2 carbon steels with up to 0·70 of vanadium resembled carbon steels in microscopic structure; with more than 0·70 per

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[*] *Revue de Métallurgie*, 1904, pp. 390–401, with fourteen illustrations.

[†] *La Métallurgie*, vol. xxxv. p. 1343.

[‡] *Stahl und Eisen*, vol. xxiv. pp. 610–611; *Iron and Steel Magazine*, vol. viii. pp. 253–256; *Journal of the Iron and Steel Institute*, 1904, No. I. p. 659.

cent. of vanadium "carbide" began to be visible in addition to pearlite; and when the vanadium exceeded 3·0 per cent. the pearlite disappeared and only "carbide" was present. This "carbide" is either a simple vanadium carbide or else a double carbide of iron and vanadium. With regard to their mechanical properties, the first series is distinctly better than is the similar carbon steel without vanadium. As the vanadium increases beyond this limit, however, the steel begins to deteriorate greatly in quality, becoming brittle and losing in hardness altogether independently of the carbon contents. Details of the test results are given.

A. F. Wiener* deals with the properties and uses of vanadium steel, giving two photomicrographs of the material and a number of tensile tests of carbon, nickel, tungsten, and chromium steels to which vanadium has been added. In all cases the tensile strength and elastic limit is raised considerably, while the elongation and contraction of area are reduced. Reference is frequently made to the work done by J. O. Arnold.

Physical Properties of Iron made by Electric Methods.—B. Neumann † discusses the physical properties of the iron and steel made by the various electric reduction methods. The hard steel melted by Siemens in his original crucible method amounted to less than 20 lbs. in the hour, and the metal produced was always full of blowholes. When he melted white pig iron in a clay crucible it appeared to remain unchanged, and when coke was added it was converted into a grey iron in about 15 minutes, graphite separating out when the metal cooled. Spiegeleisen on being fused showed the separation of carbon, while grey pig iron and 10 per cent. ferro-silicon were not affected. Wrought iron and steel in these earlier methods were very deleteriously affected by the treatment, as the author shows, and those modern methods by which steels are produced endeavour so far as may be possible to avoid the earlier sources of difficulty previously experienced.

Stassano, like Siemens, works with an arc, in his case over a yard in length, but the arrangements of the plant are quite different. The arc is horizontal, and during the fining process the metal is protected from its action by a layer of slag. Analyses are given of samples containing from 0·084 to 0·120 per cent. of carbon. The sulphur

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* *Engineer*, vol. xcviii. pp. 18–19.

† *Stahl und Eisen*, vol. xxiv. pp. 821–826, 883–888.

according to Lucchinis is apt to be too high. In the analyses referred to it varied from 0·046 to 0·130 per cent. What kind of products are made in the Conley furnace is unknown. The results of mechanical tests made with metal produced by the Keller method proved very satisfactory, and the author gives details as to tests made by himself with metal produced at Gysinge in Sweden by the Kjellin method, while similar tests by A. Wahlberg and others are also referred to. The results were generally most satisfactory, the samples examined proving of excellent quality.

The Tempering of Tool Steels.—H. Le Chatelier[*] contributes a note on certain experiments carried out with a view to determining the relation, if any such exists, between the cutting qualities of a tool and (1) the elastic limit of the steel employed, and (2) the mineralogical hardness as distinct from elastic limit. Both series of hypotheses proved false, and he was reduced to investigating the temperatures of quenching and annealing which should bring out the best qualities of the tool steel under examination. A table of the results is appended, as well as a description of the methods employed.

Testing Machines.—Mesnager[†] describes a method of recording by means of a tracing the results obtained in testing on ordinary beam-testing machines.

Illustrations are given[‡] of a vertical Riehlé 300-ton testing machine, designed to take compression tests up to 25 feet in length, tensile tests of 22 feet, and transverse tests 10 feet long by 3 feet in width. The power is supplied by a 15 horse-power electro-motor.

A. Francis[§] describes various forms of typical testing machines, and deals successively with machines for the testing of wire, springs, chains, and cement. He discusses the method of obtaining hydraulic power for applying the load, and describes the machines used for testing by impact.

P. Breuil[||] describes the 300-ton testing machine at the testing institution of the Conservatoire Nationale des Arts et Métiers.

T. D. Lynch[¶] describes a form of chuck for holding short test pieces with shouldered or screwed ends.

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[*] *Revue de Métallurgie*, 1904, pp. 184–187.

[†] *Ibid.*, pp. 193–197, with three illustrations.

[‡] *Iron Age*, July 21, pp. 18–19.

[§] *Page's Magazine*, vol. iv. pp. 503–507.

[||] *Génie Civil*, vol. xlv. pp. 137–141.

[¶] Paper read before the American Society for Testing Materials, June 1904; *Iron Age*, June 30, 1904, p. 15.

Illustrations are given[*] of a 100-ton chain-testing machine built by S. Denison, Leeds, for a Japanese shipbuilding yard.

Testing of Materials.—W. C. Popplewell[†] discusses the degree of accuracy necessary and obtained in testing materials. The points dealt with are accuracy in determining stresses, in the testing machines themselves, in calibrating the machines, in measuring the test pieces, and in reporting the results of yield point, maximum strength, elongation, and contraction.

J. P. Snow[‡] proposes a test for detecting brittleness in structural steel. A crop end of considerable size is nicked and bent in a vice by a roller. Inspection of the fracture determines the quality.

Rails.—R. W. Hunt[§] insists that mechanical treatment is of greater importance than chemical composition in steel rails.

A section of railway in Philadelphia has been laid with rails weighing 142 pounds per yard.[‖]

S. T. Wagner[¶] gives some notes of extended observations on the creep of rails on railways, and ascribes it as largely due to wave motion on defective beds.

In a paper read before the Verein für Eisenbahnkunde, A. Haarmann[**] gives particulars as to the comparative wear in practice of acid and basic Bessemer steel rails on certain sections of German railways. The acid metal gave the best result. This he thinks was in part due possibly, in some cases at least, to the way the rails were rolled, and he is of opinion that it is not advisable to roll out heavy rails with too high an end temperature. The tendency is then for a heavy rail to cool too slowly, and so to remain too soft.

Girders.—Schüle[††] gives the results of bending tests of rolled and of riveted girders with special reference to the Grey girder.

Tubes.—Tests of the tubes used for lining deep boreholes are given by Nowosielecki.[‡‡]

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[*] *Engineer*, vol. xcviii. p. 84.

[†] *Engineering Review*, vol. xi. pp. 81–89.

[‡] Paper read before the American Society for Testing Materials, June 1904; *Iron Age*, June 23, 1904, pp. 33–34.

[§] *Transactions of the American Institute of Mining Engineers*, February 1904.

[‖] *Iron Trade Review*, July 14, 1904, p. 35.

[¶] *Proceedings of the American Society of Civil Engineers*, vol. xxx. pp. 462–474.

[**] *Stahl und Eisen*, vol. xxiv. pp. 919–920.

[††] *Schweiz. Bauzeitung*, 1904, pp. 243–247, 260–263.

[‡‡] *Österreichischen Chemiker und Techniker Zeitung*, August 15, 1904.

Werner * discusses the advantages and disadvantages of Mannesmann cast iron and steel pipes for water and gas.

Wire Ropes.—The methods of testing high-grade wire ropes for strength and ductility are described by L. C. Moore.† A new method of testing wires is described by A. Falkenau,‡ and the effects of bending stresses on wire rope are discussed by J. B. Richards.§ A bibliography of wire ropes has also been published.||

Structural Steel.—S. T. Wagner ¶ gives an historical account of the use of structural steel, having a tensile strength of 60,000 pounds, in the United States, twenty years ago.

W. Forsyth ** advocates the use of steel in the construction of railway passenger vehicles.

Steel Plates and Armour.—C. Bach †† gives the results of tensile tests of fifteen old and new boiler plates at ordinary and high temperatures.

The *Naval Annual* ‡‡ deals very fully with the question of the thickness and disposition of armour for naval purposes in view of the greater penetrating power of recent projectiles, especially when they are capped.

Special Steels for Motor-Car Construction.—The special steels suitable for automobile construction are discussed.§§ The desire to reduce as far as possible the dead weight of the automobile has led necessarily to the use of steels of special kinds in order to enable the various parts of the motor-car to be made as slight as possible. Steels of this kind have been exhibited at the late motor-car exhibition at Frankfort-on-the-Main by Krupp and by Felix Bischoff of Duisburg. The former firm supplies the steel in bar or ingots or in a semi-manufactured form. One such steel, termed motor-car steel, has an elastic limit of 31·1 kilogrammes per square millimetre, a tensile

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* *Journal für Gasbeleuchtung*, 1904, pp. 517–521.

† *Mines and Minerals*, vol. xxiv. p. 405.

‡ *Ibid.*, p. 406. § *Ibid.*, p. 441. || *Ibid.*, p. 459.

¶ Paper read before the American Society for Testing Materials, June 1904; *Iron Trade Review*, June 30, 1904, pp. 52–54.

** Paper read before the Master Car Builders' Association, Saratoga, June 1904; *Engineering News*, vol. li. pp. 608–610.

†† *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. pp. 1300–1308, 1342–1348.

‡‡ Portsmouth, 1904.

§§ *Stahl und Eisen*, vol. xxiv. pp. 827–830, with eight illustrations.

strength of 54·9 kilogrammes, an elongation of 25·8 per cent., and a reduction of area of 58·2 per cent. This is not a steel suitable for the construction of any portions of a motor-car that are likely to be subjected to any severe strain, or for such portions that are not required to have the metal in them reduced to too great an extent. For parts such as these a second kind of steel, termed "special steel," is manufactured, which in addition to toughness possesses a high tensile strength and elasticity. The tests of this steel showed an elastic limit of 67·9 kilogrammes, a tensile strength of 87·2 kilogrammes, an elongation of 14 per cent., and a reduction of area of 55·6 per cent. Illustrations are given of bent specimens of this steel to show its high degree of toughness. A third type of this steel, known as "special nickel steel," has a still higher tensile strength and elastic limit, with a slightly increased elongation and reduction of area. A number of other similar kinds of steel are also referred to. The uses to which these and other kinds of steel can best be put to in motor-car construction are briefly dealt with. Similar steels made by the other firm mentioned are also described.

Testing Institutions.—N. J. P. Castanheira das Neves * has an article on the mechanical testing institutions in England, France and Spain.

E. Leduc † describes the testing establishment of the Conservatoire National des Arts et Métiers, Paris.

Large new testing laboratories in connection with the Berlin Technical High School were opened at Easter, the building being situated near the Gross-Lichterfelde-West station. An official account of these have been published by M. Guth.‡ All kinds of materials and substances will be tested. Thus the first section of the plant will deal with metals and the various materials, such as leather and wood, used in connection with the construction of machinery. The second section will deal with building materials, the third with paper, the fourth with metallography, the fifth with general chemistry—all kinds of analyses and assays, and the sixth with oils, soaps, fats, &c. The building has been erected and fitted up by the State, the cost having been over £100,000 for the building itself and some £30,000 for the fittings.

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* *Revista de Obras publicas e Minas.*

† *La Revue Technique*, vol. xxv. No. 12.

‡ J. Springer, Berlin, 380 pp., 6 plates and numerous figures in the text; *Stahl und Eisen*, vol. xxiv. pp. 807–813, with two illustrations.

The new testing plant at Gross-Lichterfelde-West is also described by Memmler.*

Standard Sections.—An octavo volume † of 59 pages is the latest outcome of the work of the Engineering Standards Committee appointed in April 1901 by the Institution of Civil Engineers and supported by the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, and the Institution of Electrical Engineers. The lists of standard sections were drawn up by three sub-committees dealing with the sections used in ship building, in bridges and building construction, and in railway rolling-stock underframes, presided over by Archibald Denny, Sir Benjamin Baker, and Sir Douglas Fox respectively. In the list a sufficient number of sizes is included to ensure satisfactory graduation, whilst at the same time reducing the number of rolls which steelmakers would find it necessary to stock. Nine lists are given dealing respectively with equal angles, unequal angles, bulb angles, bulb tees, bulb plates, Z bars, channels, beams, and T bars. In each case sketches, reference number and code word, size, standard thickness, radii, weight per foot, sectioned area, centre of gravity, moments of inertia, radii of gyration, angle and moments of resistance are given.

The Engineering Standards Committee have issued as an interim report the British standard specification for tubular tramway poles.‡ It should be understood that this is final as far as the specification is concerned and only an interim report of the Engineering Standards Committee as a whole, all reports being considered as interim until the final report of the committee, combining all reports and specifications, is issued. Besides other points, the specification states that the over-all length of poles, whether sectional or taper, shall be 31 feet, and the thickness of metal in any pole shall not be less than ¼ inch. The sectional poles shall be either solid drawn or lap-welded wrought steel, free of all defects, made up in three sections, swaged together when hot so as to make a perfect joint. The lap-welded seams in the sections shall be set at an angle of 120 degrees to each other. The taper poles shall be of wrought steel, free of all defects, rolled in one length, and butt welded the entire length.

Another report issued by the Engineering Standards Committee §

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* *Dinglers Polytechnisches Journal*, 1904, pp. 506–508.

† "Properties of British Standard Sections," issued by the Engineering Standards Committee, 1904. London: Crosby Lockwood and Son. Price 5s. net.

‡ London: Crosby Lockwood and Son, August 1904. Price 5s. net.

§ *Ibid.* Price 10s. 6d. net.

deals with bull-headed railway rails. The specification has been drawn up by a committee, of which J. C. Inglis is chairman. The chemical composition prescribed is as follows: Carbon, 0·35 to 0·5 per cent.; manganese, 0·7 to 1; silicon, not to exceed 0·1; phosphorus, not to exceed 0·075; and sulphur, not to exceed 0·08. Dimensions and drawings are given of standard rails from 60 to 100 pounds per yard. The ultimate tensile strength must be not less than 38 tons per square inch, with an elongation of not less than 15 per cent. The sections follow the trend of modern practice.

Testing Cast Iron.—Various reports on specifications for different classes of cast-iron castings have appeared.* Incidently a discussion took place between W. J. Keep and T. D. West on the relative value of the square and round test-bar.

Specifications for cast-iron railway wheels have also appeared.†

C. B. Dudley ‡ gives standard specifications for cast-iron railway wheels.

B. F. Fackenthal § gives chemical specifications for pig iron. This subject also received attention from E. S. Cook.||

H. Souther ¶ deals with the need of standard specifications for grey iron castings.

W. Wood,** in two papers, discusses standard specifications for cast-iron pipe and locomotive cylinders.

H. C. Loudenbeck,†† D. Reid, J. G. Wilson, and others point out the value of the chemist and metallurgist in foundry work. A. M. Loudon ‡‡ gives a note on the metallurgy of cast iron, and H. E. Diller §§ discusses hard-iron and its causes. J. J. Porter |||| gives some examples of irregular distribution of sulphur in pig iron, and F. C. Everett ¶¶ deals with the manner in which the metal contains carbon. H. L. Williams *** deals generally with the effect of elements present in pig iron.

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* Paper read before the American Society for Testing Materials, June 1904; *Engineering News*, vol. li. p. 584.

† Paper read before the Master Car Builders' Association, June 1904; *Engineering News*, vol. li. pp. 614–615.

‡ *Transactions of the American Institute of Mining Engineers*, February 1904.

§ *Ibid.* || *Ibid.*

¶ *Ibid.* ** *Ibid.*

†† Paper read before the American Foundrymen's Association, Indianapolis, June 1904.

‡‡ *Ibid.* §§ *Ibid.*

|||| *Ibid.* ¶¶ *Ibid.* *** *Ibid.*

C. H. Wingfield[*] draws attention to the permanent set in cast iron due to small stresses, and discusses its bearing on the design of piston-rings and springs.

Steel Specifications.—Specifications are given[†] for boiler plate, rivet steel, steel castings, and steel forgings.

H. V. Wille[‡] advocates a chemical and physical specification for axles and forgings as a compromise between various existing specifications, and applicable to both basic and acid steel.

J. L. Replogle[§] discusses the manufacture and specifications of steel axles. Hammers used for forging iron axles were not sufficiently heavy for steel, but satisfactory forgings were obtained with larger hammers. The Coffin toughening process, or oil tempering and annealing, enable perfectly satisfactory axles to be made. The author recommends, however, one or two alterations in the specification of the Master Car Builders. These include an increase in the carbon percentage limits, 0·40 to 0·50 being specified instead of 0·35 to 0·50. At the same time the phosphorus limit is to be decreased from 0·07 to 0·05. All axles should be annealed and should be forged to the finished size as nearly as possible.

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[*] *Report of the Seventy-third Meeting of the British Association.* London, 1904, p. 788.

[†] *Transactions of the American Society of Mechanical Engineers*, vol. xxiv. pp. 921–928.

[‡] Paper read before the American Society for Testing Materials, June 1904; *Iron Age*, June 30, 1904, p. 22.

[§] Paper read before the Western Railway Club, May 1904; *Engineering News*, vol. li. pp. 471–472.

CHEMICAL PROPERTIES.

The Passive State.—Müller [*] ascribes the passive state to a modification of the theory that there is a physical change in the metal itself. It is explained by the electron theory, a deficit of negative electrons being supposed to occur. Müthmann supports the oxide skin theory.

Electrolytic Iron.—A. Skrabal [†] distinguishes two essential different methods yielding two different kinds of electrolytic iron. In the first method a ferrous salt is used as electrolyte, and iron as anode, with a low voltage and a low current density. He calls iron produced by this method A-iron. The second method is characterised by the use of platinum as anode, high voltage, high current density, and an electrolyte containing bivalent iron in some complex form. Iron made by this method is called by him B-iron. The A-iron is of silver-white colour, compact and extremely hard. The B-iron is of more greyish colour, less compact and less hard. Since the conditions of these two methods may be combined at will—for instance, ferrous chloride as electrolyte, iron as anode, high current density and voltage, or complex ferrous salt as electrolyte, iron as anode and low current density—it is possible to get a great many different kinds of electrolytic iron which in their properties are more or less similar to A- or B-iron. The author gives some historical data on experiments made by various investigators.

Foundry Iron.—O. Leyde [‡] traces the spread of the recognition of the value of a knowledge of the chemical composition of the pig

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[*] Paper read before the German Society of Electro-Chemists; *Engineer*, vol. xcvii. p. 584.

[†] *Zeitschrift für Elektrochemie*, September 23, 1904.

[‡] *Stahl und Eisen*, vol. xxiv. pp. 801–807, 879–883.

iron used in foundry practice. At one time this was scouted, and the value of the pig iron was adjudged solely from its appearance on fracture. Even now, without taking into consideration its chemical composition at all, a pig iron with a dark, large crystal fracture is called No. I., and one with a lighter and fine-grained fracture No. III. In part, however, it is now customary at German works to require that a No. I. iron shall have over 3 per cent. of silicon and but little sulphur, and that a No. III. iron shall have under 3 per cent. of silicon and a higher sulphur contents. This is by no means common, however, and the author shows that the same haphazard relationship of the numbers and of the chemical composition exists in the United States. Thus, comparing the analyses of different numbers of pig irons made at over ninety works in the United States, he finds this to be as follows:—

Metals Described as	Silicon Contents.
	Per Cent.
No. I. . . .	0·90 to 4·00
No. II. . . .	0·35 ,, 3·80
No. III. . . .	0·40 ,, 3·10
No. IV. . . .	0·20 ,, 2·40
No. V. . . .	0·10 ,, 1·75
No. I. soft . .	2·10 ,, 5·50
No. II. soft . .	2·30 ,, 4·50

The numbers used by the different works therefore mean nothing at all, or but very little, so far as the silicon contents is concerned. The author instances a case where a foundryman having a great deal of high silicon iron desired to purchase pig iron containing but little silicon in order to lower the average contents. He therefore ordered a No. III. iron, expecting to get one with some 2 to 2·5 per cent. of silicon. Instead of this, the No. III. iron sent him contained 4 per cent. of silicon, and was even higher in silicon than the metal he had already. The author quotes from a report by the Seymour R. Church Company of San Francisco, which, after communication with some 300 ironworks scattered all over the world, give analyses of the different numbers from each of these. An examination of the silicon contents shows how very different this is in the same numbers at different works. This is evidenced by the following figures given as representing the No. I. irons made by the works mentioned:—

Works.	Silicon Per Cent.
W. Baird & Co.	2·50
Bell Bros.	3·17
Bolckow, Vaughan & Co.	3·00
Palmer Shipbuilding Co.	2·30
Alabama Consolidated Co.	2·75 to 2·50
Bass Foundry and Machine Co.	1·50
Kittanning Iron and Steel Co.	3·25 to 2·25

In order that castings of all kinds may be made with some degree of certainty, the chemical composition of the metal should be known and a guaranteed composition should be required.

A paper by R. Moldenke * on foundry iron is discussed, especially in connection with the author's statements as to the presence of ferrous oxide in cast iron. This ferrous oxide is present dissolved in the pig iron and scrap that are to be used for a casting. In casting rolls it is found that, owing to the enormous molecular strains which result when the mass of metal forming the roll is cooling down, many such rolls crack even before they cool. To avoid this the foundryman of experience buys certain kinds of iron which he finds give the best results when used for this purpose. These are not the purest kinds of iron, but those which his practical knowledge shows him to have the least tendency to crack when the roll is cast. This is noticed, too, in other branches of the foundry industry. What is the reason for this difference of behaviour? The author considers that it is largely due to the presence or absence of ferrous oxide. For cast iron manganese is of less value as a reducing agent for this than it is in the case of steel, the temperature of the molten metal being so much lower. Aluminium, however, gives very good results as a reducing agent. It cannot, however, be used if the iron is low in silicon, as it leads to the formation of graphite, and in certain cases would render the casting useless. Titanium, on the other hand, appears to be capable of being used with equal advantages, but without this disadvantage other elements will probably also prove efficacious in this connection.

Chemical Systems of Classification of the Constituents of Steels.—H. Le Chatelier † points out that where substances display a graduated range of characteristics, passing insensibly from one extreme to another, classification becomes extremely diffi-

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* *Stahl und Eisen*, vol. xxiv. pp. 527–529; *The Iron and Steel Metallurgist*, vol. vii. pp. 26–29.

† *Revue de Métallurgie*, 1904, pp. 207–225, with sixteen illustrations.

cult. He instances the geological variation of rocks which pass, sometimes almost imperceptibly, into each other, and are not distinctly marked off as are minerals and palæontological specimens, or animals and plants. A similar instance, chemically, is afforded by liquid water and molten potassium nitrate, which have apparently nothing in common except fluidity, but between which it is possible to have a range of solutions varying from one of water with a few thousandths of the potassium salt in solution and one of the salt itself, having but a few thousandths of water in solution, forming a continuous series which seems to defy classification. He sees, however, in the phase law, a method for introducing some order and classification amongst metals and alloys, particularly those of the carbon series. He would likewise call to his aid the microscopic structure to assist in devising a system of classification. He passes from general considerations to that of steel constituents, and after briefly reviewing the chief characteristics of these constituents he suggests a system of classification applicable in their case. After touching on the distinctions between eutectoids, hypo-eutectoids, hyper-eutectoids, eutectics, and hyper- and hypo-eutectics, he concludes by some simple illustrations of the distinctions between phase, aggregation, and structure, comparing them respectively with mineral constituents of rocks, with the rocks themselves, and with the vague conditions of texture known as the amphorous, the crystalline, &c.

Nitrogen in Steel.—E. A. Sjöstedt* discusses the presence of nitrogen in steel and its effect, quoting from the opinions expressed by H. Braune† and C. Bolin. The percentage of nitrogen in the metal is considered to depend in part on the formation of the cyanides in the blast-furnace. Hot working and fast driving tend to increase the amount, and the same effect is produced by an increase in the basicity of the slag. Braune's directions for the dimensions and methods of working blast-furnaces for various kinds of iron, in which nitrogen is low, are also quoted.

Segregation and Diffusion in Steel.—B. F. Weston‡ discusses the problems of segregation and diffusion in steel, quoting some of Howe's investigations of the former and some researches by Arnold and McWilliam on the latter. The author then gives some of his

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* *Iron Age*, May 5, 1904, pp. 33–35.

† *Teknisk Tidskrift*, *Kemi och Bergsvetenskap*, vol. xxxiv. pp. 24–26.

‡ *Iron Age*, May 19, 1904, pp. 28–29.

own carbon determinations by colorimetric and combustion methods in basic open-hearth steel ingots.

Phase Law.—In a paper read before the German Bunsen Society, H. W. Bakhuis-Roozeboom[*] discussed the application of the phase law to the mixture of iron and carbon. The relationship of temperature and carbon contents is not yet finally settled. The question of the stability of cementite at high temperatures is also raised, and the author is of the opinion that it is very unstable.

Corrosion of Iron and Steel.—G. T. Moody[†] has published the second part of his investigation on the influence of soluble substances on the rusting of iron, which he considers due largely to the reaction of carbonic acid or other acid with the iron, and subsequent oxidation of the ferrous salt. On the other hand, W. R. Dunstan in recent papers puts forward a view that hydrogen peroxide plays an important part in the reaction. He considers that the following reactions occur:—

$$Fe + O_2 + H_2O = FeO + H_2O_2,$$
$$2FeO + H_2O_2 = Fe_2O_2(OH_2).$$

The author strongly opposes this explanation. Compounds which inhibit rusting all react with carbonic acid, and thus prevent its attacking the iron. Either a direct absorption may occur, as with substances having an alkaline reaction; or the carbonic acid replaces the weak acid contained in the salt, such as potassium nitrite, sodium acetate or potassium ferrocyanide.

At the June meeting of the American Society for Testing Materials,[‡] much discussion took place on the question of preservative coatings for iron and steel. It is shown that at present there is much diversity of opinion and lack of definite knowledge, also that service and accelerated tests only give comparative results. Various tests are also proposed, and the methods of testing are generally compared.

J. W. Schaub[§] deals with some of the phenomena of the adhesion of steel and concrete.

An exhaustive report by A. P. Ford on experiments made at

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[*] *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 317; *Engineer*, vol. xcvii. p. 583.

[†] *Proceedings of the Chemical Society*, vol. xix. pp. 239–241.

[‡] *Engineering News*, vol. li. pp. 583–584.

[§] *Ibid.*, pp. 561–562.

McKeesport regarding the corrosion of iron and steel boiler-tubes has been published.*

According to Diegel † a plate of malleable iron was hung in sea water for a period of one year. The whole surface was then found to have been strongly and irregularly corroded. The plate contained:—

C.	Mn.	Ni.	Cu.	Si.	P.	S.
0·05	0·44	0·07	0·08	0·01	0·071	0·06

Copper similarly treated was scarcely affected, but various kinds of bronze and nickel-copper alloys were badly attacked.

Investigations have also been made by Diegel ‡ on the influence exerted by phosphorus and nickel on the corrosion of iron by sea water. Earlier experiments by Otto and by Rudeloff appeared to show that phosphorus exerted no marked influence, but Baucke subsequently mentioned a case in which locomotive tubes with 0·1 per cent. of phosphorus withstood corrosion well, while others with only 0·02 per cent. of phosphorus were rapidly corroded. This led the author to make further experiments, full details of which are now given. They show that a higher percentage of phosphorus tends to slightly lower the extent to which iron is corroded by sea water, but as it also affects the quality of the metal only certain portions of a ship's hull or boilers could be protected by increasing the phosphorus percentage. How this may best be affected the author shows. Iron containing nickel, if in contact in sea water with an iron alloy containing much less nickel, is hardly corroded at all or only slightly, whereas the iron low in nickel is rapidly attacked. The best use of nickel steel is also dealt with. H. Rinne § discusses these results.

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* *Journal of the American Society of Naval Engineers*, 1904, pp. 529–546.

† *Stahl und Eisen*, vol. xxiv. p. 573.

‡ *Ibid.*, pp. 629–639.

§ *Ibid.*, pp. 639–642.

CHEMICAL ANALYSIS.

CONTENTS.

I.—ANALYSIS OF IRON AND STEEL.

Ironworks Analysis.—Recent progress in the analysis of iron and steel is summarised by H. Wedding.[*]

C. H. White[†] deals with the equipment of a laboratory for metallurgical chemistry in a technical school.

H. Göckel[‡] has devised a form of shield by which it is claimed the meniscus can be well seen and clearly determined when the burette is being used in volumetric analysis.

A. Gwiggner[§] has devised a funnel for rapid filtration.

Determination of Iron. — A. Skrabal[||] finds that electro-deposited iron produced from ferrous ammonium oxalate contains both carbon and hydrogen, and may, indeed, be considerably impure. Indeed, its actual value for standardising purposes, in the permanganate volumetric method, is according to his investigations only 98·53 to 99·90 of the theoretical value. He suggests that a current of 0·3 to 0·4 volt should be used, but Classen[¶] states that the deposited iron is pure even with a current of 7 to 8 volts provided the deposition is stopped early enough.

[*] *Chemiker Zeitung*, vol. xxviii. pp. 660–663.

[†] *Transactions of the American Institute of Mining Engineers*, February 1904.

[‡] *Stahl und Eisen*, vol. xxiv. p. 580, with three illustrations.

[§] *Ibid.*, p. 580.

[||] *Zeitschrift für Analytische Chemie*, vol. xlii. p. 359.

[¶] *Ibid.*, p. 516.

Ferric oxide and iodine react together as follows:—

$$Fe_2Cl_6 + 2KI = 2FeCl_2 + 2KCl + I_2.$$

The iodine so separated must be then determined by thiosulphate in the ordinary manner. Carcano[*] and Namias, however, now maintain that the volumetric method for the determination of iron which is based on this reaction is inaccurate, as in addition to the principal reaction the iodine liberated reacts with the ferrous salt also formed, in the following manner:—

$$2FeCl_2 + 2HCl + I_2 = Fe_2Cl_6 + 2HI.$$

The titration can therefore give accurate results only if the iodine formed is immediately withdrawn from the action of the ferrous salt. They therefore evaporate the iron solution with hydrochloric acid, after oxidation with nitric acid, take up the residue and dilute the solution until it contains only 1 to 2 per cent. of iron. It is then neutralised with sodium carbonate and 5 to 10 per cent. of hydrochloric acid is added. In addition 2 grammes of potassium iodide is added, and then from 5 to 10 grammes of chloroform, and the whole titrated back with thiosulphate.

Determination of Manganese.—L. L. de Koninck[†] discusses the choice of the oxidising agent for ferrous salts in view of the volumetric determination of manganese. Chlorates and permanganates may advantageously be chosen if iron is titrated with tin chloride, nitric acid if the acetate method is used, and bromine if manganese is to be precipitated at the same time. Bromine is unsuitable if it has to be evaporated off, owing to the fact that the iron bromide loses bromine.

L. L. de Koninck[‡] gives a method for the direct volumetric determination of manganese in the presence of iron by means of potassium permanganate.

H. Lüdert[§] has examined the persulphate method for the determination of manganese. In this the manganese is converted into persulphate, which is then decomposed by boiling and the manganese peroxide dissolved in standardised hydrogen peroxide, the excess of the latter being next determined by potassium permanganate. This

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[*] *Boll. Chem. Farm.*, 1904, pp. 43, 54; *Stahl und Eisen*, vol. xxiv. p. 891.

[†] *Bulletin de l'Association belge de Chimistes*, vol. xviii. p. 90; *Chemisches Centralblatt*, 1904, No. II. p. 64.

[‡] *Bulletin de l'Association belge de Chimistes*, vol. xviii. p. 56; *Chemisches Centralblatt*, 1904, No. I. p. 1429.

[§] *Zeitschrift für Angewandte Chemie*, vol. xvii. p. 422.

method he finds to give satisfactory results, but he suggests that the tedious solution in sulphuric and nitric acids should be replaced by the use of nitric acid by itself. This causes the solution to be more completely and rapidly effected. Further, he avoids the slow filtration of the carbon and the neutralisation with ammonia, separating only the graphite. He adopts the method of titrating the hydrogen peroxide direct as proposed originally by von Knorre, while Ledebur filters the manganese sulphate and dissolves the precipitate in ferrous sulphate. The author found that even an 82 per cent. ferro-manganese could be readily dissolved in nitric acid. His method generally is as follows: in the case of an iron containing 0·6 per cent. of manganese, 4 grammes is dissolved in a 1 litre Erlenmeyer flask in 50 cubic centimetres of nitric acid of 1·2 specific gravity, the solution being finally completed at the boil. The solution is then diluted with water to 400 cubic centimetres, 40 cubic centimetres of sulphuric acid of 1·18 specific gravity and 50 cubic centimetres of a solution containing 120 grammes of ammonium persulphate to the litre being then added. The solution is boiled for half-an-hour, 15 cubic centimetres of standardised hydrogen peroxide solution being then added, the excess being titrated back with permanganate so soon as the manganese peroxide has dissolved. The hydrogen peroxide solution corresponds to about an equal volume of permanganate solution, but it is so unstable that it must be checked every day with standardised permanganate solution.

It is pointed out * that in the gravimetric determination of manganese in iron ores the manganese sulphide produced is extremely difficult to separate from the filter. This not only leads to loss but also to great waste of time. It is probable that ammonium sulphide is the cause of this trouble. The following method of treatment, however, yields satisfactory results. The manganese sulphide on the filter should be washed with absolute alcohol until the whole of the ammonium sulphide has been eliminated. This point can be determined by the filter being then quite colourless, whereas it would previously be tinged yellow by the ammonium sulphide. The funnel should be kept covered during the process to prevent the alcohol evaporating and causing the ammonium sulphide to creep towards the edge of the filter. The alcohol is then washed away by ether, and the precipitate allowed to dry. This treatment leaves the manganese sulphide in a very finely divided form which can be easily separated from the filter.

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* *Stahl und Eisen*, vol. xxiv. p. 835.

No manganese passes into either the alcohol or the ether filtrates. Manganese ores should be ignited before being dissolved, to destroy organic matter, if volumetric methods are to be subsequently employed. The ore might well be dissolved by treatment with hydrofluoric and sulphuric acids, evaporating, taking up with hydrochloric acid, and then treating in the usual manner.

Determination of Sulphur.—A. Silfverling * describes the modification of Wiborgh's method in use at the Stockholm School of Mines, a filter being introduced in order to secure a uniform coloration.

A. P. Ford † and O. G. Willey, discussing the determination of sulphur in iron, strongly recommend H. Kelway-Bamber's method.

S. S. Knight ‡ gives a rapid method for the determination of the total sulphur in iron by evolution.

C. A. Leyler § has tested the various methods for the determination of sulphur in pig iron which depend on the elimination of the sulphur by acids as hydrogen sulphide. As is well known, the results obtained are too low. The best results are obtained by passing the evolved gases in a current of hydrogen through a red-hot tube.

L. Fricke ‖ discusses the determination of sulphur in pig iron and steel by means of titration with iodine and thiosulphate. This he considers to be one of the best methods for laboratory use, being very rapid and giving accurate results. The author has employed the following method for about a year in the laboratory of the Peine rolling-mills. About 5 grammes of pig iron, or 10 grammes of steel, are placed in a stoppered flask, into which is run 100 cubic centimetres of water and 75 of concentrated hydrochloric acid, the flask being of from one-half to one litre capacity. This is then heated over not too strong a flame. The flask is connected with a vertical condenser in which most of the hydrochloric acid vapours and steam condense and run back into the flask. The sulphuretted hydrogen vapours evolved first pass into a dry flask, and then pass through three others. The first is merely intended for safety in case the solution from the next flask should run back. In this latter flask is about 40 cubic centimetres of a solution of cadmium acetate. This solution contains 25 grammes of the salt and 200 cubic centimetres of glacial acetic acid per litre. Following on

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* *Jernkontorets Annaler*, vol. lix. pp. 114–115.

† *Journal of the American Chemical Society*, vol. xxvi. pp. 801–808.

‡ *American Chemical Journal*, vol. xxxii. No. 1.

§ *The Analyst*, vol. xxviii. p. 97.

‖ *Stahl und Eisen*, vol. xxiv. pp. 890–891, with one illustration.

this flask is another, which contains a few cubic centimetres of the same solution with a view to ascertaining whether the absorption of the sulphuretted hydrogen has been complete. A current of carbon dioxide is passed through the apparatus so soon as the evolution of gas has ceased. The contents of the cadmium solution flask are then washed into a half-litre Erlenmeyer flask and diluted to about 150 cubic centimetres. It is next titrated with iodine solution and a solution of sodium thiosulphate 1 cubic centimetre of which corresponds to 1 milligram of sulphur, *i.e.*:—

α 7·928gI + 25gKI in the litre.
β 15·526g$Na_2S_2O_3$ + 2g$(NH_4)_2CO_3$ in the litre.

An excess of the iodine solution is first added, then about 75 cubic centimetres of dilute hydrochloric acid (850 cubic centimetres H_2O + 300 cubic centimetres concentrated HCl of 1·124 specific gravity) and then titrated back with the thiosulphate after first adding about 2 cubic centimetres of a solution of zinc iodide. From the difference between the cubic centimetres of the iodine and thiosulphate solutions used, the percentage of sulphur is at once obtained.

Determination of Arsenic.—R. Nowicki * describes a new distillation apparatus for the determination of arsenic, the chief point being the condensation arrangements. The material to be examined is dissolved in nitric acid, evaporated several times with a little sulphuric acid, taken up with concentrated hydrochloric acid, and transferred to the distillation flask. After the addition of from 30 to 40 cubic centimetres of a saturated solution of iron chloride, the contents of the flask are brought to 250 cubic centimetres, and then completely saturated with hydrochloric acid gas. Using a rapid current of hydrochloric acid gas about half the volume of the solution is distilled off, and condensed in a cooler of special construction, a current of water passing through a central core which is removed when the distillation is complete. The distillate is diluted, the orifice left by the removal of the core cooler closed, and a current of hydrogen sulphide passed through the liquid. The arsenic can be determined as sulphide, or by a volumetric method with iodine after neutralisation by means of sodium bicarbonate.

Determination of Nitrogen.—E. A. Sjöstedt † gives Braune's method for determining nitrogen in iron and steel. The nitrogen is

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* *Stahl und Eisen*, vol. xxiv. pp. 771–772, with one illustration.
† *Iron Age*, May 5, 1904, pp. 33–35.

converted into ammonia by dissolving the metal in hydrochloric acid, the ammonia is removed by distillation with a base and is determined by Nessler's solution. Full details are given.

Determination of Chromium.—B. J. Glasmann * describes a volumetric method of determining chromium and iron in mixtures of the two metals.

F. Southerden † advocates the separation of iron and chromium by means of fused potassium nitrate. The operation can be effected in a few minutes and may be applied even in the case of chrome iron ore. The dry precipitate is fused with nitre, small quantities of potassium bisulphate being added. The precipitation is effected by ammonia, and the precipitate is dissolved in hydrochloric acid and the iron determined. The chromic acid is precipitated by silver nitrate.

E. Jaboulay ‡ determines the various constituents of ferro-chromium in the following manner:—

0·2 gramme of the metal is heated from 4 to 6 hours in a current of oxygen, the carbon dioxide formed being passed into an ammoniacal solution of barium chloride. This solution is made by dissolving 150 grammes of barium chloride in 900 cubic centimetres of water and 100 cubic centimetres of ammonia of 22 Bé. strength. After the absorption of the carbon dioxide the ammonia present is driven off, the barium carbonate collected by filtration, the barium in this determined as sulphate, and the carbon determined by calculation. The chromium, iron, aluminium, and silicon are determined as follows: 1 gramme of the sample is fused with 20 grammes of potassium hydrogen sulphate. The fused material is allowed to cool, moistened with concentrated sulphuric acid, fused again, taken up with water, precipitated with ammonia, filtered, the filter and its contents boiled up with 150 cubic centimetres of nitric acid of 36 Bé. strength, 20 grammes of potassium chlorate being also added. If a greenish residue still remains, this must be fused again with more bisulphate. The chromate solution is diluted, the silica filtered off, the iron and alumina precipitated by ammonia, and the chromate solution in turn is reduced to oxide and also precipitated by ammonia. The iron and alumina are separated in sulphuric acid solution by the Carnot method,

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* Paper read before the Russian Physical and Chemical Society, April 29, 1904; *Chemiker Zeitung*, vol. xxviii. p. 575.

† *Chemical News*, vol. lxxxix. p. 183.

‡ *Revue Génerale de Chemie pure et appliqué*, vol. vi. p. 210

the alumina being precipitated as phosphate and the iron in the filtrate determined by titration.

To estimate the manganese and sulphur, 12 grammes of soda are heated to redness, a similar quantity of sodium peroxide added, and the mixture is again heated to redness ; 3 grammes of the ferro-chromium are then added. The whole mass is kept in fusion for a further period of about 10 minutes, cooled, taken up with water, and filtered. The filtrate is evaporated, taken up with hydrochloric acid, filtered, and the sulphuric acid in the filtrate determined in the usual way. The residue from the filtration is dissolved in hydrochloric acid, evaporated with nitric acid, and the manganese precipitated by potassium chlorate.

A further quantity of 4 grammes of soda and 4 grammes of sodium pèroxide is fused as above and then 1 gramme of the ferro-chromium added for the phosphorus determination, the whole kept fused for another 12 minutes, taken up with water and nitric acid, precipitated with ammonia, the precipitate dissolved in hydrochloric acid, evaporated, silica separated, the hydrochloric acid in the filtrate expelled, taken up with nitric acid and the phosphoric acid present in the solution precipitated as molybdate in the ordinary manner.

E. Jaboulay * also gives a method for determining chromium in steel.

Determination of Molybdenum.—F. van D. Cruser † and E. H. Miller describe various methods for determining molybdenum in steel and steel alloys, and give particulars of a method they have devised for the purpose.

Reaction Test for Titanic Acid.—A. Jorrisen ‡ describes a reaction for titanium compounds. A trace of the suspected substance is fused with six times its weight of potassium bisulphate on a platinum loop. The resulting fusion is crushed by a glass rod in a solution of 1 or 2 cubic centimetres of salicylic acid in 20 or 30 drops of pure concentrated sulphuric acid, when the particles slowly become tinged with red, which gradually spreads through the whole liquid. The colour is similar to that of the sulpho-cyanide reaction with iron salts.

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* *Revue Génerale de Chemie pure et appliqué*, vol. vi. p. 468; *Chemisches Centralblatt*, 1904, No. I. p. 318; *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 80.

† *Journal of the American Chemical Society*, vol. xxvi. pp. 675–695.

‡ *Bulletin de l'Academie Royale des Sciences de Belgique*, 1903, p. 902.

Determination of Vanadium.—E. Campagne* reduces vanadium in solution to a lower oxychloride by prolonged boiling with hydrochloric acid, adds sulphuric acid to turn it into the corresponding blue sulphate, and then titrates with permanganate. When applied to steel, the bulk of the iron chloride is removed by ether.

A number of methods for the determination of vanadium in iron and steel are referred to or described.† They include, among others, those of Williams, Trüchot, Corminboeuf, and Blair. The latter, which is the one most generally used, consists in dissolving in nitric acid, igniting the nitrates, and fusing the resulting oxides with sodium carbonate and nitre. The fused mass is extracted by water, the alumina precipitated with sodium carbonate, which precipitate, however, always takes down some vanadium as well, and then, in the filtrate, the vanadium, chromium, and tungsten are precipitated together as mercury salts. The precipitate is decomposed by heating, and the vanadic acid converted into a vanadate by fusion with an alkali carbonate. This is then converted into ammonium meta-vanadate, and this by ignition into V_2O_5. The method is, however, cumbersome and inaccurate. Arnold recommends, in the case of steel, the fusion of 5 grammes of the powdered steel with 25 to 30 grammes of sodium peroxide in a nickel crucible, and then determining the vanadium by Blair's method. P. Nicolardot, on the other hand, dissolves the metal out of contact with air in very dilute hydrochloric acid. The vanadium is then stated to remain undissolved. After separating the graphite and silicon, the vanadium is weighed as V_2O_5. This method is, however, quite inaccurate, as some of the vanadium passes into solution. Another method, proposed by Carnot, is to precipitate the vanadium as penta-sulphide, which is soluble in sulpho-hydrates. Yet another method, proposed by Campagne, consists in reducing the V_2O_5 by hydrochloric acid, and then titrating with permanganate. This method gives satisfactory results, and is as follows: 5 grammes of the steel turnings are dissolved in 60 cubic centimetres of 1·20 nitric acid, some water being first put into the flask, and then the acid dropped in little by little, cooling if necessary. Then evaporate until red fumes cease to be given off, dissolve in hydrochloric acid, and evaporate to about 40 cubic centimetres. Cool, extract as in the Rothe method, dilute with hydrochloric acid to 60 cubic centimetres, add 100 cubic centimetres of ether, shake, cool, and separate the layers.

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* *Comptes Rendus*, vol. xxxvii. p. 570.

† *Stahl und Eisen*, vol. xxiv. pp. 834–835.

The aqueous solution is generally of a beautiful green colour, rarely brown in tinge. It is evaporated to a small volume, the residue taken up with 50 cubic centimetres of hydrochloric acid, again partially evaporated, taken up as before, and again evaporated. In this way all the vanadium is converted $VOCl_2$. The residue is taken up with 5 cubic centimetres of concentrated sulphuric acid, evaporated on the water bath, cooled, and then taken up with from 250 to 300 cubic centimetres of warm water. If large quantities of silica are present, this must be filtered off. The titration is effected at a temperature of 60° C., the termination of the titration being very easy to recognise. The coloration with permanganate must remain constant for 30 minutes.

For steels with over 2 per cent. of vanadium, 2·5 grammes of the metal are taken for the analysis. In the case of iron ores, 10 grammes of ore is dissolved in concentrated hydrochloric acid, the excess driven off, and the solution then shaken up with ether, and treated as before.

For the separation of vanadium from aluminium and iron, B. J. Glasmann * adds sufficient potassium iodide and dilute sulphuric acid (1 : 5) to the solution containing vanadium, together with aluminium or iron, and heats the mixture for twenty minutes, the iodine being dissolved by sulphurous acid. The solution is neutralised by potassium hydroxide until the precipitate begins to separate. This is then dissolved in a few drops of strongly-diluted acid, and the solution diluted to 100 cubic centimetres with water. A few cubic centimetres of a mixture of 20 per cent. potassium iodide and 7 per cent. potassium iodate solutions are then added. The precipitation of the ferric or aluminium hydroxide is completed by heating on the water bath for half-an-hour. The iodine is dissolved in thiosulphate, and the ferric or aluminium hydroxide filtered off, washed well, ignited, and weighed. The filtrate containing vanadium trioxide is evaporated to dryness, with the addition, firstly, of sulphuric acid to remove the iodine, then of nitric acid to form vanadium pentoxide, and finally of sulphuric acid to displace the nitric acid. The residue is dissolved in water, acidified with sulphuric acid, mixed with sulphurous acid to reduce the V_2O_5 to V_2O_4, and when the excess of sulphurous acid is removed by boiling and passing a stream of carbon dioxide through the liquid, the latter is titrated at 70° with potassium permanganate solution. The method is found to give good results.

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* *Journal of the Russian Physical and Chemical Society*, vol. xxxvi. pp. 314–317.

Separation of Iron and Chromium.—F. Southerden[*] recommends that the precipitate containing the hydroxides of iron, aluminium, and chromium should be dried, placed in a test-tube, a little potassium nitrate added, and the whole cautiously heated until fused. A small piece of potassium hydrogen sulphate is then added, and the heating continued until brown fumes are evolved copiously. The chromium is thus completely oxidised, and may be separated from the iron and aluminium in the usual manner. Even chrome-iron ore is decomposed sufficiently to give a decided reaction for chromium.

Separation of Zinc and Iron.—O. Herting[†] considers that Flath's method of twice precipitating by ammonia is accurate enough for works determination of zinc, but the separation is perfect if ammonium acetate is used with the ammonia.

Electrolytic Methods of Analysis.—M. Krüger[‡] deals fully with modern methods of electrolytic analysis. The elements dealt with include mercury; the separation of mercury and silver, and of these two from selenium; the separation of silver from antimony; antimony; the separation of antimony from tin; arsenic; bismuth, and its separation from other elements, such as chromium, nickel, and iron; separation of lead from manganese; the determination of manganese; the separation of iron and manganese, of aluminium and iron, and of zinc and iron. Zinc, nickel, and thallium are also dealt with. According to G. P. Scholl, manganese should be determined in a solution made slightly acid with either acetic or formic acids. To separate manganese from iron, he adds formaldehyd, or formic acid and sodium sulphite. The iron separated, however, contains carbon. J. Köster uses for this separation an addition of phosphorous acid, which is intended to reduce any manganese peroxide that may form. To prevent in this separation the precipitation of iron at the anode, Hollard and Bertiaux employ sulphurous acid. This also prevents aluminium from falling out with the iron when iron and aluminium are being separated. Zinc and iron cannot be separated quantitatively in a potassium cyanide solution, as some iron always falls out with the zinc. The marked increase in rapidity

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[*] *Chemical News*, vol. lxxxix. p. 183.

[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. p. 89.

[‡] *Elektrochemische Zeitschrift*, 1904; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 399–400.

of deposition which results when the electrolytes are put into rapid movement is noted. A list is given of a number of recent papers dealing with electrolytic methods of analysis.

II.—*ANALYSIS OF IRON ORES AND SLAGS.*

Determination of Lime and Alumina.—C. E. Rueger [*] points out a liability to error in the determination of lime and alumina in slags when rapid methods are employed. If the iron and alumina are simply precipitated once with ammonia, they carry much of the lime with them. Examples are given.

Determination of Fluorine in Open-Hearth Slag.—L. Fricke [†] points out that at the Peine Steelworks, fluorspar is added in the open-hearth process to render the slag more fluid, and it became of interest to ascertain how much of the fluorine passed into the slag. In view of the phosphoric acid present the methods in use for the determination of fluorine in vitreous products were not suitable. Similarly it was found that the method proposed by Gläsern for the direct determination of the fluorine as calcium fluoride in silicates containing phosphoric acid, was not applicable, due to the large excess of potassium carbonate that had to be employed owing to the difficulty experienced in melting the slag. The method finally adopted was as follows: 5 grammes of the slag in a very finely powdered condition is fused in a platinum crucible for 30 minutes to 1 hour with five to six times its weight of potassium carbonate. The cooled mass is extracted with water and filtered. The aqueous solution contains all the fluorine in the form of potassium fluoride, together with potassium phosphate and potassium silicate. On prolonged boiling with ammonium carbonate silica and alumina are precipitated. The solution is then cooled and filtered. In addition to small quantities of silica the filtrate still contains considerable quantities of phosphoric acid. To eliminate the whole of the first and the greater part of the latter it is heated with an excess of zinc oxide dissolved in ammonia, and finally evaporated and dried at about 120° C. The residue is taken up with cold water, filtered, and washed with a 2 per cent. solution of potassium carbonate. To the filtrate about 1 to 1·8 gramme of cal-

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[*] *Engineering and Mining Journal*, vol. lxxvii. p. 688.

[†] *Stahl und Eisen*, vol. xxiv. pp. 889–890.

cium chloride is added, acidulated with acetic acid, and heated until all the carbonic acid has been expelled. Then caustic potash is added until the solution is alkaline, when it is rendered slightly acid with acetic acid. A precipitate will then have formed, and this contains the whole of the fluorine in the form of calcium fluoride, a very small quantity of calcium phosphate being also present. This precipitate is filtered off, well washed, ignited in a platinum crucible, and weighed as $CaFl_2 + Ca_3P_2O_8$. The fluorine is determined indirectly, the phosphoric acid being determined direct, and the weight of the phosphate deducted from the total. For this purpose the residue is decomposed by heating with concentrated sulphuric acid in a platinum crucible, the phosphoric acid being subsequently determined by the molybdate method, or by this and subsequent titration with lead acetate if the quantity of phosphoric acid is but small. If large, the molybdate precipitate is dissolved and the phosphoric acid determined by the use of magnesia mixture.

III.—*ANALYSIS OF FUEL.*

Fuel Analysis.—G. P. Lishman* deals with the analytical valuation of gas coals, and gives a bibliography of the subject.

Bertelsmann † also deals with the valuation of gas coals.

Determination of Moisture in Coal.—When coal is dried in air, accurate determinations of moisture are not possible, as chemical changes take place under the influence of the oxygen of the air. To avoid these, R. Nowicki ‡ has designed a glass drying vessel in which the coal can be dried in a current of hydrogen, and subsequently weighed. The author has also designed a modified apparatus for use in connection with gas analysis.

Determination of Total Carbon in Coal.—In a method described by S. W. Parr, § the coal is oxidised with sodium peroxide in the calorimetric bomb recently described, || and, after decomposing the excess of the reagent by boiling with water, the carbon dioxide formed in the combustion is liberated and its volume measured,

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* *Transactions of the Institution of Mining Engineers*, vol. xxvii. pp. 516–528.

† *Glückauf*, vol. xl. pp. 1250–1253.

‡ *Stahl und Eisen*, vol. xxiv. p. 772, with two illustrations.

§ *Journal of the American Chemical Society*, vol. xxvi. pp. 294–297.

|| *Journal of the Iron and Steel Institute*, No. I. 1901, p. 360.

due allowance being made for any carbon dioxide contained in the sodium peroxide.

Determination of Coke.—E. J. Constam * and R. Rougest describe the various methods in use for the determination of the coke yield of coals and coal briquettes. The Bochum method is shown to be the best.

Analysis of Flue Dust.—E. A. Sjöstedt † gives Bolin's method for the determination of cyanogen and its compounds in flue dust. The aqueous extract of the dust is precipitated in the dark with silver nitrate, the cyanogen compounds are successively extracted from other compounds in the precipitate by nitric acid and ammonia, and the determination of the silver gives an indirect method of estimating the cyanogen compounds.

IV.—*GAS ANALYSIS.*

Apparatus.—H. C. Babbitt ‡ describes a modified form of a stationary Hempel apparatus, devised by W. J. Knox, and the method of using it for gas analysis.

Illustrations are given § of the Krell-Schultze apparatus for determining the percentage of carbonic anhydride in the products of combustion. Air and the gas to be tested are drawn at approximately equal rates through two tubes which are connected to a differential pressure gauge, of which the movement indicates the composition of the gas. An automatic photographic recorder is used in conjunction with the gauge.

J. B. C. Kershaw || discusses fuel economy in steam plants from the chemist's point of view, and illustrates a carbonic acid testing apparatus for works use.

Unconsumed Constituents in Smoke Gases.—W. H. Sodeau ¶ describes the determination of the unconsumed constituents in smoke gases. In those from Welsh coals 0·65 per cent. was found, and in those from Texas petroleum 1·2 per cent.

* *Zeitschrift für Angewandte Chemie*, vol. xvii. p. 737.

† *Iron Age*, May 5, 1904, p. 34.

‡ *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xx. pp. 252–256.

§ *Engineering*, vol. lxxvii. pp. 629–630.

|| *Cassier's Magazine*, vol. xxvi. pp. 40–47.

¶ *Chemical News*, vol. lxxxix. pp. 61–63.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the official statistics* the British production of iron ore in 1903 was as follows:—

	Amount.	Value.
	Tons.	£
From mines	9,078,384	2,730,958
From quarries	4,637,261	498,979
Total	13,715,645	3,229,937

The production of pig iron in 1903 is officially stated to have been 8,935,063 tons. In its production 21,878,902 tons of iron ore and 18,302,240 tons of coal were used. There were 349 furnaces in blast.

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* *Mines and Quarries: General Report and Statistics for* 1903. Part III.: Output.

The total output of coal was 230,334,469 tons, which is the largest on record, for it exceeds by 3,239,427 tons the quantity produced in 1902. The consumption of coal in the United Kingdom amounted to 166,529,120 tons, or nearly four tons per head of the population. 18,302,240 tons of coal were used in blast-furnaces for making pig iron. The quantity of coal exported, exclusive of coke, patent fuel, and coal shipped for use of steamers engaged in foreign trade, was 44,950,057 tons, an increase of 1,791,011 tons compared with the preceding year. If the quantities of patent fuel, coke, and coal shipped for use of steamers engaged in foreign trade be added, the total amount of coal which left this country was 63,805,349 tons.

Iron Trade Statistics.—The British Iron Trade Association[*] gives the production of pig iron in the United Kingdom in the first half of 1904 as amounting to 4,048,965 tons. This is a decrease of 330,033 tons on the production in the first half of 1903 and a decrease of 47,513 tons on the production of the first half of 1902. The same authority also gives the production of other products in the first half of 1903, as follows:—Bessemer steel ingots, 865,683 tons, against 911,670 tons in the first half of 1903 and 888,378 tons in the first half of 1902. Bessemer steel rails, 523,771 tons, against 483,964 tons in the first half of 1903 and 410,420 tons in the first half of 1902. Open-hearth steel ingots, 1,670,129 tons, against 1,639,239 tons in the first half of 1903 and 1,710,602 tons in the first half of 1902.

The first volume of the report[†] of the Chamberlain Tariff Commission, relating to the iron and steel trades, has been issued.

A summary of the conclusions arrived at has also been published.[‡]

Blast-furnace Statistics.—The accompanying statistics are compiled from returns received direct from the furnaces, and published at the office of the *Iron Trades Circular* (Ryland's):—

Total number of furnaces built on June 30, 1904 . . .	536
Total number of furnaces in blast on June 30, 1904 . .	327
Decrease in the number of furnaces built since March 31, 1904	3
Increase in the number of furnaces in blast since March 31, 1904	3

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[*] *Iron and Coal Trades Review*, vol. lxix. p. 977.

[†] *Report of the Tariff Commission*, vol. i.; *Iron and Steel Trades*, London, 1904.

[‡] *Iron and Coal Trades Review*, vol lxix. pp. 260–261.

Coal.—An official list of mines in the United Kingdom for the year 1903 has been issued. For each district there are two lists; the first list is arranged alphabetically according to the names of the mines, whilst the second is arranged alphabetically according to the names of the owners. The principal list gives the name and situation of each mine, the name and address of the owner or company, the name of the manager, the number of persons employed underground and above ground, and the nature of the minerals worked.

A Blue Book has also been issued giving a list of the plans of abandoned mines.

II.—*AUSTRALASIA.*

Mineral Statistics of New South Wales.—The quantity * of coal produced during 1903 was 6,354,846 tons, valued at £2,319,660, as compared with 5,942,011 tons, of the value of £2,206,598, raised during 1902. The number of persons employed in coal and shale mines during the year was 14,117, as against 13,114 persons employed in 1902. Of these 13,917 were employed on coal mines, and 200 on oil and shale workings. Of the coal produced, the production in the Northern district was 4,410,565 tons, that of the Southern district being 1,476,005 tons, and the Western district 468,276 tons. 160,592 tons of coke were made, of the value of £108,763.

Mineral Statistics of Victoria.—According to the official statistics † the production of coal in Victoria in 1903 amounted to 64,200 tons, valued at £40,818. There was also produced 5661 tons of brown coal, valued at £2827. A strike accounts for the decrease in production.

Mineral Statistics of Tasmania.—According to official returns ‡ the output of coal in Tasmania in 1903 amounted to 49,069 tons, of the value of £42,447.

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* *Annual Report of the Department of Mines, Sydney*, 1904, pp. 33, 37.

† *Annual Report of the Secretary for Mines, Melbourne*, 1904, p. 21.

‡ "Tasmania." Report of the Secretary for Mines for Half-Year ending December 31, 1903. Including Reports of the Commissioners of Mines, Inspectors of Mines, Government Geologist, Assistant Government Geologist, Mount Cameron Water-Race Board, &c. (Hobart: Department of Mines.)

Mineral Statistics of New Zealand.—According to the official statistics, the coal production of New Zealand in 1903 showed an increase of 55,189 tons in comparison with the previous year, the total output being 1,420,229 tons.*

III.—*AUSTRIA-HUNGARY.*

Mineral Statistics of Austria.—The Austrian official statistics † show that the production of the mines and works of Austria in 1903 included the following:—

	1903. Metric Tons.
Iron ore	1,715,984
Manganese ore	6,179
Graphite	29,590
Asphalt rock	1,273
Coal	11,498,111
Brown-coal	22,157,521
Coal briquettes	122,164
Brown-coal briquettes	56,969
Coke	1,168,263
Forge pig iron	808,633
Foundry pig iron	162,199
Total pig iron	970,832

Of the total value of the mineral production Bohemia yielded 49·21 per cent., Silesia 17·55 per cent., Styria 13·87 per cent., Moravia 9·99 per cent., Galicia 2·28 per cent., Carinthia 2·08 per cent., and Carniola 1·57 per cent. Altogether 138,882 miners were employed, 48·00 per cent. of them being engaged in coal mining, 39·64 per cent. in brown-coal mining, and 3·56 per cent. in iron ore mining.

A volume has been published ‡ containing particulars of wages paid in Austrian mines in 1901, arranged on a new plan. The statistics given relate exclusively to mines and dressing floors, metallurgical works, and coke works being excluded. The net earnings, after all deductions for material and insurance have been made, vary from 3s. 10d. per shift for brown-coal getters at Teplitz to 7d. per shift for lads in Galicia.

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* *Iron and Coal Trades Review*, vol. lxix. p. 1133.

† *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums*, 1903; Part II. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 385–386.

‡ *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums*, 1901; Part IV. (Vienna, Government Printer, 1904).

The official report on the mining pension and sick funds for the year 1902 has been issued.* The volume consists of 189 quarto pages of closely-printed figures. During the year under review the membership of the benefit funds amounted to 178,492.

Petroleum and Ozokerite in Galicia.—The Austrian official statistics † show that in 1902 there was produced in Galicia 529,847 tons of petroleum and 2655 tons of ozokerite, increases respectively, as compared with the outputs in 1901, of 28·71 per cent. and 13·60 per cent. At the 292 active petroleum workings 5889 workpeople were employed, all but eleven being men, while at the ozokerite mines 2610 workpeople were engaged. There were ten fatal and ninety-three severe accidents at the workings, and twenty fatal and six severe accidents at the ozokerite mines. One explosion at an ozokerite mine caused eighteen deaths.

Brown Coal in North-West Bohemia.—According to the statistics collected by the Aussig-Teplitz Railway Company, now issued for the thirty-fifth year,‡ the total output of brown coal in North-West Bohemia in 1903 amounted to 18,301,641 tons, an increase of 83,828 tons as compared with the output in 1902.

The rise in the brown coal industry of Bohemia dates, according to Saueracker.§ from the increase of transport facilities, due to the railways constructed in 1858. In Bohemia itself less than half the output is utilised, the rest being exported.

Austrian Mining Schools.—F. Schraml ‖ describes the mining schools of Austria, dealing with the courses of study pursued, and the lines on which developments will or should be introduced.

IV.—*BELGIUM.*

Mineral Statistics.—During the first half of 1904 there was produced in Belgium 11,605,900 tons of coal, 650,150 tons of pig

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* *Statistisches Jahrbuch des k.k. Ackerbau-Ministeriums.* Part III. (Vienna, Government Printer, 1904.)

† *Ibid.* Part II. (Vienna, Government Printer, 1903.)

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 373–374.

§ *Ibid.*, pp. 283–284.

‖ *Ibid.*, pp. 200–205.

iron, 180,950 tons of wrought iron, and 522,750 tons of steel ingots.*

In Belgium † in 1903 there were 115 collieries in operation, 287 shafts being at work. The total output was 23,913,240 tons. With the exception of 1873, the year 1903 was the best recorded in the history of Belgian coal-mining.

Firket,‡ the inspector-general of mines in the province of Liége, has published his annual report for 1903. The production of coal in the province amounted to 6,478,110 tons, the greatest output yet recorded. There were 35,322 workpeople employed at the collieries, the mean daily wage being 3s. 4d. The production of coke was 656,330 tons, the yield being 76·3 per cent. There were sixteen blast-furnaces in operation, the total production of pig iron being 606,091 tons. The consumption of coke was 1·110 ton per ton of pig iron produced.

C. Minsier,§ chief inspector of mines at Mons, has published his report of the iron and coal industries of Hainaut in 1903. The production of coal in the province was 16,544,570 tons, 100,372 workmen being employed. The production of coke was 2,046,840 tons, 2757 coke-ovens being in operation. There were thirteen blast-furnaces at work, the production of pig iron being 436,140 tons.

The Belgian imports‖ of coal amounted to 1,815,137 tons, and the exports to 2,302,290 tons during the first half of 1904.

An article has been published ¶ on the history of the Belgian coal-mines from 1810 to 1900.

A report on the time worked by Belgian miners has been issued.** The figures vary from 7 to 12½ hours underground.

V.—*CANADA.*

Pig Iron Statistics.—There is a decrease in production of 12,287 tons, or a little over 9 per cent., in the first half of 1904, as compared with the first half of 1903, and as compared with the second half of

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* *Moniteur des Intérêts Matériels*, vol. liv. p. 2483.

† *Chemische Zeitschrift*, vol. iii. p. 599.

‡ *Moniteur des Intérêts Matériels*, vol. liv. pp. 2481–2482.

§ *Ibid.*, pp. 2905–2907.

‖ *Ibid.*, p. 2295.

¶ *Ibid.*, p. 2057.

** *Annales des Mines de Belgique*, vol. ix. pp. 775–779.

1903 it was 11,845 tons, or a little less than 9 per cent. Of the total production, 35,291 tons were basic pig iron, against 69,325 tons in the first half of 1903 and 57,567 tons in the second half of that year. A small quantity of Bessemer pig iron was produced in the second half of 1903, but no Bessemer pig iron was made in the first half of 1903 or the first half of 1904.*

On June 30, 1904, Canada had fifteen completed blast-furnaces, of which six were in blast and nine were idle. Of this total, eleven were equipped to use coke and four to use charcoal. In addition, one coke furnace was being built on June 30, 1904, and one coke and one charcoal furnace were partly erected, but work was suspended.

The total number of furnaces in Canada actually in blast for the whole or a part of the first half of 1904 was ten, of which seven used coke and three used charcoal.

Mineral Statistics.—J. Obalski † gives the following statement showing the mineral production of Quebec for the year 1903:—

	Short tons of 2000 lbs.	Value. Dollars.
Magnetic and titanic iron ore .	112	300
Bog iron ore	12,035	34,985
Chrome ore	3,020	45,300
Ochre (calcined) . . .	1,746	20,440

There were 9636 tons of charcoal pig iron made, valued at $230,639; using 20,646 tons of ore, of which 10,746 tons of bog ore were from this province, the balance coming mostly from Ontario.

According to the official statistics ‡ the production of coal in British Columbia in 1903 was 1,168,194 tons.

VI.—*CHINA.*

Mineral Resources of Indo-China.—In Tonkin, some thirty-six miles from Hanoi, rich iron ore beds have been discovered. Not far from these beds are the collieries of Hon-gay, where anthracite is mined, which mixed with Japanese bituminous coal yields a serviceable metallurgical coke.§

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* *Colliery Guardian Supplement*, October 7, 1904, p. 25.

† *Engineering and Mining Journal*, vol. lxxvii. p. 800.

‡ *Report of the Minister of Mines, Victoria*, 1904, p. 12 and p. 217.

§ *Stahl und Eisen*, vol. xxiv. p. 857.

The production of coal during 1903 amounted to 267,333 metric tons, of which the manufacture of briquettes consumed 37,877 metric tons. The bulk of the coal is exported, but the production last year fell considerably short of that of 1902.*

VII.—*FRANCE.*

Iron Trade Statistics.—It is reported † that during the first half of 1904 France produced 1,193,214 tons of forge pig iron, 287,423 tons of foundry pig iron, 264,910 tons of wrought iron, 17,354 tons of iron plates, 137,619 tons of rails, 464,120 tons of merchant steel, and 149,911 tons of steel plates.

The iron industry of the Haute-Marne is described by M. Bulard.‡

There were in operation in France 66 blast-furnaces in the east, 12 in the north, and 30 in the centre, making a total of 108.§

The five iron works in France with the greatest production are those of Wendel with 700 tons of pig iron daily, of Micheville with 675 tons, of Longwy with 650 tons, of Denain and Anzin with 540 tons, and of the Marine with 525 tons.

During the first half of 1904 the French imports included 13,884 tons of pig iron, 13,711 tons of wrought iron, and 4761 tons of steel, whilst the exports included 87,553 tons of pig iron, 34,420 tons of wrought iron, and 105,828 tons of steel. ||

Coal.—The production of coal in France in 1903 was 34,317,527 tons, and that of lignite 685,465, making a total of 35,002,992 tons.¶

The production of coal in the Pas de Calais and Nord fields during the first half of 1904 amounted to 11,223,140 tons,** and the production of coke during the first half of 1904 amounted to 762,746 tons.

The French official mining statistics for 1902 have just been issued. The total mining production was 36,668,921 tons, including 29,997,470 tons of coal, and 4,465,472 tons of iron ore.

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* *Iron and Coal Trades Review*, vol. lxix. p. 483.

† *Echo des Mines*, vol. xxxi. p. 1154; *Comité des Forges de France*, Bulletin No. 2456.

‡ *Annales de Géographie*, vol. xiii. No. 70.

§ *Echo des Mines*, vol. xxxi. p. 787.

|| *Moniteur des Intérêts Matériels*, vol. liv. p. 2619.

¶ *Annales des Mines*, vol. v. p. 389.

** *Moniteur des Intérêts Matériels*, vol. liv. p. 2364.

The French official statistics * for the year 1902 give the following information with regard to the coal and brown-coal industries of that country :—There were in 1902 in France 381 concessions in active operation, an increase of 31 on the year. Of these 315 related to coal and anthracite and 66 to brown coal. The total output was 20,997,000 metric tons, a diminution as compared with the output in 1901 of 7·2 per cent. This decreased output was chiefly due to a strike. Of the total output 93·1 per cent. was bituminous coal, 4·8 per cent. anthracite, and 2·1 per cent. brown coal. The average value of the whole output per ton at the collieries was 14·55 francs. The collieries consumed 3,309,000 tons of coal and brown coal and the other mines 85,000 tons. The workpeople employed at the collieries and brown-coal mines numbered 164,800, of whom 46,100 were employed above ground. . The average wage per shift below ground was 4·99 francs, the average output per man and per shift being 0·951 ton. The total accidents numbered 19,276 below ground and 1220 at surface, 120 workpeople being killed and 22,613 injured, 96 per cent. of these injuries being but slight. There were 5 fire-damp explosions involving 9 deaths,

E. Lozé † gives a detailed account of the French mining industry as shown at the exhibition at Arras. The exhibits indicate the great improvements being made in the use of superheated steam as motive power, the rapid progress in the construction of gas-engines utilising poor gas, and the development of the applications of electricity in mines.

The production of peat in France in 1902 amounted to 110,000 tons.‡ The department of the Somme, with 44,000 tons, was the leading producing district. The total value of the production was 1,674,000 francs.

Mineral Statistics of New Caledonia.—A report § has been published of the Governor's speech at the opening of the General Council. He gave the following statistics of production :—

Ore.	1903. Tons.	Average of last 5 years. Tons.
Nickel	77,360	108,411
Chromium	21,437	14,456
Cobalt	8,292	4,930

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* *Statistique de l'Industrie minérale en France et en Algérie pour l'année* 1902. Paris, 1904.

† *Annales des Mines de Belgique*, vol. ix. pp. 577–605.

‡ *Chemische Zeitschrift*, vol. iii. p. 599.

§ *Bulletin du Commerce de la Nouvelle Calédonie*, vol. vi. No. 265.

VIII.—*GERMANY.*

Iron Trade Statistics.—The production of pig iron in Germany during the first six months of 1904 amounted to 4,999,413 metric tons, as compared with 4,934,532 tons during the same period of the preceding year. The production of the different kinds of pig iron was as follows':—

	Metric tons.
Foundry pig iron	898,890
Bessemer	220,873
Basic	3,174,401
Steel iron and spiegeleisen	293,813
Forge pig iron	411,436
Total	4,999,413

Of this Rhenish Westphalia made 1,960,176 tons, and Lorraine and Luxemburg 1,637,321 tons.*

The consumption of pig iron in Germany, including Luxemburg, is calculated † to have been as follows in the years given :—

Year.	Total Consumption.	Consumption per Head of Population.	Production per Head of Population.
	Metric Tons.	Metric Tons.	Metric Tons.
1880 . . .	1,752,534	0·0393	0·0612
1890 . . .	3,920,951	0·0817	0·0971
1900 . . .	7,377,339	0·1317	0·1521
1901 . . .	5,102,508	0·0903	0·1395
1902 . . .	4,367,330	0·0766	0·1496
1903 . . .	5,650,404	0·0981	0·1739

The position of the German iron trade in the world's markets is discussed in great detail by A. Weiskopf.‡ The paper contains an elaborate collection of statistics and diagrams.

C. Schott § gives the German iron trade exports for each of the years 1900–1903, and compares these with those from the United Kingdom for the same years. Similar details for the exports from Belgium and the United States are also given.

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* *Stahl und Eisen*, vol. xxiv. p. 917.

† *Ibid.*, p. 473.

‡ *Zeitschrift für angewandte Chemie*, 1904, pp. 1233–1246, 1265–1274.

§ *Stahl und Eisen*, vol. xxiv. pp. 590–592.

The annual report of the Essen Chamber of Commerce [*] contains interesting details of the works of the F. Krupp Company. The number of persons employed in 1903 was 45,289. The works consumed 867,206 tons of coal, 460,539 tons of coke, and 9282 tons of briquettes.

Iltis[†] discusses the accidents in iron works in North-West Germany. The statistics investigated extend from October 1, 1885, to December 31, 1902. Only 21·5 per cent. of the accidents and only 12 per cent. of the deaths were caused by machinery.

Iron Ore.—Statistics [‡] are given showing the importance of the minette iron ore district of Lorraine and Luxemburg. In 1890 the German Customs Union produced 11,406,132 tons of iron ore, 6,615,683 tons of which consisted of minette. In 1903 the iron ore production was 21,230,639 tons, that of minette being 16,693,054 tons.

In 1903 the minette iron ore district of Lorraine and Luxemburg produced 10,017,901 tons. In 1890 the production was 4,658,450 tons.

O. Bosselmann[§] observes that the output of iron ore in Lorraine and Luxemburg amounts to more than three-fourths of the output of the whole of Germany, while the production of pig iron is 30 per cent. of the total German production. The iron ore reserves of Lorraine are estimated at 3000 million tons, while the ore reserves of Luxemburg contain about 123 million tons. Freight charges form 30 per cent. of the cost in Germany per ton of pig iron, while the author claims they only amount to 8 per cent. in the United Kingdom. In Lorraine and Luxemburg the conditions are more favourable in this respect, for although 1 ton of pig iron requires 3 tons of ore, only 1 ton of coal is necessary. Thus the cost of transport to Düdelingen is but 9·42 shillings as compared with 19·82 to Gelsenkirchen.

The Chambers of Commerce[||] of Saarbrücken, Treves, and Coblenz have addressed a memorial to the German Parliament in favour of the canalisation of the Rivers Saar and Moselle, which they contend is urgently needed. It is pointed out in the memorial that

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[*] Reprinted in the *Centralblatt der Walzwerke*, 1904, p. 416.

[†] *Zeitschrift des Vereines deutscher Ingenieure*, vol. xlviii. p. 1190.

[‡] *Moniteur des Intérêts Matériels*, vol. liv. p. 2269.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 225–226.

[||] *Stahl und Eisen*, vol. xxiv. pp. 593–597.

Germany possesses enormous deposits of coal and iron ore. Its largest coalfields, with an annual output of some 60 million tons, are on the Lower Rhine, in the Ruhr district. Its most important deposits of iron ore are in Lorraine and Luxemburg. The minette deposits of the Upper Moselle are estimated to contain 3000 million tons of ore, and the yearly output from this field is now some 16 million tons out of the 21 millions representing the output of iron ore in the whole of Germany. The only source of transport between these coal and iron ore deposits is now the railway, but this is inadequate, as the cost of transport is still high. It is pointed out that the German iron trade is now, and must continue to be, largely dependent on the sale of its products in foreign markets, and commercial success in this direction is dependent on the reduction to a minimum of transport charges. It is also noted that in Germany some 28 to 30 per cent. of the first cost of pig iron is due to the cost of transport, whereas in the United Kingdom the proportion is only 9 to 10 per cent. of the total first cost of the ton of pig iron.

The cost of the canalisation of the two rivers in question is dealt with, as well as the probable income to be derived from their subsequent use. It is shown that in the Rhenish-Westphalian district there was produced in 1903 in round figures 2·5 million tons of basic pig iron. Minette from Lorraine is a most suitable ore, and it is probable that 3 million tons of such ore would be utilised annually at these furnaces in addition to other ores. Again in Lorraine, Luxemburg, and the Saar district some 4 million tons of pig iron were made in 1903, most of which was exported, while no less than 3,650,000 tons of coke was sent in 1903 to these three iron-making districts from the Ruhr field. It is shown that these exports are even now considerably in excess of what would be needed to insure the financial success of this project.

Coal.—The production of coal in Germany in 1903 was 116,637,765 tons, that of brown coal 45,819,488 tons, that of coke 11,007,000 tons, and that of briquettes 1,780,000 tons.*

The production of coal in Germany and Luxemburg during the first half of 1904 amounted to 58,825,710 tons, and that of brown coal to 23,251,206 tons.†

In the Dortmund mining district in 1903 there were 509 fatal accidents or 1·977 per 1000 workmen employed.‡

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* *Moniteur des Intérêts Matériels*, vol. liv. p. 2907.

† *Ibid.*, p. 2407.

‡ *Glückauf*, vol. xl. p. 869.

Petroleum.—The German production of petroleum has considerably increased of late years. In 1902 the production of crude oil was 49,725 tons, and in 1903 it was 62,780 tons, or 27·1 per cent. more. In 1881 the output was only 1309 tons.*

Mineral Statistics of Prussia.—The Prussian mineral production † in 1903 included, in metric tons, coal 108,809,384, brown coal 38,462,766, asphalt 23,518, petroleum 41,733, iron ore 3,786,743, nickel ore 14,057, and manganese ore 47,110. The metallurgical production included, in metric tons, pig iron 6,614,767, and nickel 1945.

In Prussia in 1903 there were 558,152 persons engaged in mining, and of these 1006 lost their lives during their work. This represents 1·802 per 1000. The accident rate was 1·989 in collieries, 2·165 in brown-coal mines, 1·681 in salt-mining, and 1·034 in ore-mining. There were 30 fire-damp explosions in Prussia in 1903.

Iron Trade Statistics of Upper Silesia.—In 1903 at 57 collieries in Upper Silesia there were employed 82,927 workpeople, an increase of 2·9 per cent. as compared with the previous year.‡ The coal raised amounted to 25,235,649 tons, an increase of 3·1 per cent. as compared with the output in 1902.

At the iron ore mines 2499 workpeople were employed. The iron ore raised amounted to 369,189 metric tons, a diminution on the year of 13·8 per cent.

The quantity of coal raised daily in Upper Silesia is about 70,000 tons. The wages paid have risen considerably in recent years, and the number of workpeople employed has risen far more rapidly than has the output of coal. Good hewers made up to £70 as wages, but the average wage paid was £48, 12s.§

G. Bresson ‖ reviews the conditions of the iron and steel industries of Upper Silesia, giving details as to the number of works in operation, the production of coal, coke, and ores, and the manufacture of pig iron, and of manufactured iron and steel, with the number of persons employed, and the salaries paid to the workmen.

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* *Chemische Zeitschrift*, vol. iii. p. 598.

† *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate, Statistische Lieferung*, vol. lii. pp. 1–28.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 415–416.

§ *Ibid.*, pp. 256–257.

‖ *Revue de Métallurgie*, 1904, pp. 141–154.

The mining industry of Upper Silesia is described by L. Litschauer.[*] A map of the district is given, and an illustration of the Hohenzollern colliery at Beuthen. In 1902 Upper Silesia produced in addition to coal, 928,963 tons of brown coal, 449,269 tons of iron ore, and 11,811 tons of nickel ore.

Mineral Statistics of Bavaria.—The mineral production of Bavaria in 1903 included, in metric tons, coal 1,210,439, brown coal 23,599, iron ore 162,500, graphite 3719, fireclay 173,919, and fluorspar 3410. The metallurgical production included 90,168 tons of pig iron, 36,853 tons of bar iron, 21,063 tons of iron wire, and 127,141 tons of steel.[†]

Mineral Statistics of Luxemburg.—The annual report of the Luxemburg Chamber of Commerce[‡] states that the number of iron ore mines in operation advanced from 76 in 1902 to 80 in 1903, and the production of ore from 5,130,000 tons to 6,010,000 tons. There were twenty-seven furnaces in blast, and these turned out 1,220,000 tons of pig iron, as against 1,080,000 tons in 1902, the greater portion being basic pig. The output intended for sale by the two steelworks, the Düdelingen and the Differdingen, comprised 15,474 tons of ingots and 220,805 tons of semi-finished steel. As regards manufactures, the works produced 28,008 tons of rails and fish-plates, 9369 tons of sleepers, 96,476 tons of merchant iron and machinery, and 1576 tons of rolled wire. In addition to these, 11,119 tons of castings were made, these being mostly machine parts.

Metallurgical Education.—B. Osann[§] describes the new metallurgical school buildings of the Clausthal mining school. Plans and an elevation accompany the description. The building is arranged partly for iron metallurgy and partly for general metallurgy, different floors being allotted to each. Special attention is also to be devoted to fuels.

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[*] *Banyaszati es Kohaszati Lapok*, vol. xxxvii. pp. 93–117.

[†] *Zeitschrift für praktische Geologie*, vol. xii. p. 287; *Glückauf*, vol. xl. p. 702; *Berg- und Hüttenmännische Zeitung*, vol. lxiii. p. 458; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 400–401.

[‡] *Comité des Forges de France*, Bulletin No. 2455.

[§] *Stahl und Eisen*, vol. xxiv. pp. 397–399, with four illustrations.

IX.—*GREECE.*

Mineral Statistics.—The mineral production of Greece in 1903 included, in metric tons, iron ore 360,310, manganiferous iron ore 152,520, chrome iron ore 8478, manganese ore 9340, brown coal 10,700, and magnesite 25,657.*

X.—*INDIA.*

Mineral Statistics.—The official statement † issued by the Government of British India shows that there was in 1903 a satisfactory increase in the mineral production. The most important item is coal, and the output in tons was as follows:—

Bengal	6,361,212
Nizam's Territory	362,733
Assam	239,328
Central India	193,277
Central Provinces	159,154
Other districts	122,682
Total	7,438,386

The quantity of coal exported rose slightly, and amounted to nearly 500,000 tons, a large part of which goes to the Straits Settlement and to Ceylon. India now supplies nearly all her own wants in fuel, and the imports of foreign coal in 1903 amounted to only 206,829 tons, about three-quarters of which was from Great Britain. The railroads of India take a large share of the coal produced in the country, their consumption in 1903 having amounted to 2,203,889 tons. The greatest development has been in the Raniganj field, which is only about 140 miles from Calcutta. The only new movement in 1903 was in the arrangements made to manufacture briquettes from the Bikaner lignite.

The development of the petroleum resources of Burma and Assam has been very large. The production of petroleum is shown in the following table, in gallons:—

Burma	85,328,491
Assam	2,528,785
Punjab	1,793
Total	87,859,069

As with coal, the increase in petroleum production has affected the imports of foreign oil, which have largely decreased during the past few years.

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* *Montan Zeitung*, vol. xi. p. 323.

† Summarised in *Engineering and Mining Journal*, vol. lxxviii. p. 715.

The native industry in smelting iron, which has existed in most parts of India from very ancient times, has undergone a gradual decline in the face of cheaper iron and steel imported from Europe. But the industry still lingers in parts of the Madras Presidency and the Central Provinces, showing, in fact, a tendency towards improvement in the latter area. Except in Barrakar, where the conditions for the manufacture of pig iron are favourable, on account of the proximity of ore supplies and good coking coal, no successful attempt has yet been made to manufacture iron on a large scale in India.

The most remarkable development has taken place in manganese ore. The industry exists in Vizianagram and in the Central Provinces. This ore is of a very high grade, ranging from 51 to 54 per cent. metal, and is therefore able to pay the freight over 500 miles of railroad, besides the shipment charges to Europe and America. All the ore is exported. The following table shows the total output of manganese ore, in tons:—

Central Provinces	101,554
Madras	63,452
Total	165,006

Mining for graphite still continues in Travancore, although the deposits there are not as rich as those of Ceylon. The output for 1903 was only 3394 tons.

The magnesite deposit of the chalk hills in the Madras Presidency has attracted attention. The total production in 1903 was 826 tons.

XI.—*ITALY.*

Mineral Statistics.—The mineral production of Italy* in 1903 comprised:—

	Metric Tons.
Pig iron	75,279
Wrought iron	177,392
Steel	154,134
Mineral fuel	346,887
Asphalt	89,690
Iron ore	374,790
Manganiferous iron ore	4,735
Manganese ore	1,930
Graphite	7,920
Coke	21,000
Coal briquettes	693,200
Charcoal briquettes	20,595

The production of petroleum amounted to 2486 tons.

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* *Revista del Servisio Minerario*, Rome, 1904.

N. Pellati * describes the exhibits prepared by the Italian Government to illustrate the mineral resources of Italy at the St. Louis Exhibition.

XII.—*JAPAN.*

Iron Industry.—J. Terény † describes the Japanese iron and steel industries. Illustrations of the ancient methods of smelting are given, as well as details of the steelworks recently erected.

Coal.—The St. Petersburg *Vjedemosti* ‡ gives some figures on the coal industry of Japan. Japan's export of coal has risen from 4,000,000 tons, which it was ten years ago, to 7,000,000 tons, which it is at present. The coalfield which has hitherto been most exploited is situated on the island of Kiu-Siu, but it is estimated that the Yesso Island coalfield contains at least 600,000,000 tons, an amount comparable to that which has been hitherto regarded as the whole amount of Japan's available coal.

XIII.—*NATAL.*

Coal.—The annual report of the Commissioner of Mines § for 1903 shows an increase of 120,727 tons over the figures for 1902; the coal output for 1902 amounted to 592,821 tons against 713,548 tons in 1903.

While the importance of coal-mining cannot be disregarded, in spite of the increased consumption for bunkering and other purposes, no one can expect to see this branch of the industry placed on a sound footing until the local consumption needed to feed local industries is firmly established. The mining of the enormous iron deposits of the colony would increase the home consumption of coal, and become the means of bringing the coal output to a much higher figure.

XIV.—*NORWAY.*

Mineral Statistics.—The Norwegian mineral statistics for 1902 have been issued. The production included, in metric tons, chrome

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* *Rassegna Mineraria*, vol. xx. pp. 257-258.

† *Banyaszati es Kohaszati Lapok*, vol. xxxvii. p. 374-383.

‡ *Mining Journal*, vol. lxxvi. p. 376.

§ *Ibid.*, p. 477.

ore 22, molybdenite 20, nickel ore 4040, and iron ore 53,675. Of iron ore 51,000 tons were produced at the Ulefoss mines, and 1675 tons at the Klodeberg mine. Iron smelting was carried on at the Nes ironworks in Egeland, where 527 tons of pig iron were produced.

XV.—*ROUMANIA.*

Petroleum.—An article on the Roumanian petroleum industry has been published,* showing that the production of crude oil increased from 64,530 tons in 1894 to 390,000 tons in 1903. In the latter year the production of the various districts was as follows: Prahova, 350,000 tons; Dunbovita, 25,000 tons; Bacau, 10,000 tons; and Buzen, 5000 tons.

The *Moniteur du Pétrole Roumain* † has issued a special number describing the Prime Minister's visit to the Prahova oilfields. Several illustrations of the oil-wells are given. As an introduction a table is inserted showing the petroleum production of the world from 1859 to 1902. In the latter year the contribution of the various countries to the world's output was as follows, per cent.: United States, 47·94; Russia, 43·50; Dutch Indies, 3·17; Galicia, 2·24; Roumania, 1·11; India, 0·87; Japan, 0·64; Germany, 0·20; Italy and other countries, 0·33.

XVI.—*RUSSIA.*

Iron Trade Statistics.—The Russian iron trade statistics for 1903 have been published.‡ The number of blast-furnaces in operation on January 1, 1904, amounted to 163. The production of pig iron was 2,389,210 tons.

This includes the following outputs in the different divisions of the empire:—

District.	Poods.
The Ural	39,602,004
Central Russia	5,747,732
North Russia	1,496,912
South Russia	83,426,505
Poland	18,681,774

The production of pig iron was greater in the second half of the year than it was during the first half, and in the last quarter of 1903 as much as 42,043,438 poods (675,780 tons) of pig iron was produced.§

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* *Montan Zeitung*, June 15, 1904.

† Vol. v. p. 366.

‡ *Moniteur des Intérêts Matériels*, vol. liv. p. 2146; *Comité des Forges de France*, Bulletin No. 2457.

§ *Stahl und Eisen*, vol. xxiv. p. 668.

Manganese Ore.—The production of manganese ore * in Russia in 1902 was 28,649,000 poods, Brazil followed with 8,810,000 poods, India with 4,230,000 poods, Germany with 3,040,000 poods, Spain with 2,812,000 poods, and the United States with 1,020,000 poods. Since 1896 the Russian manganese ore production has doubled. The highest record was 45,946,232 poods in 1900. The manganese ore is obtained chiefly from the Caucasus, where in 1903 there were 251 mines, employing altogether 2004 workmen.

Petroleum.—Statistics of the petroleum trade of Baku in 1902 are given by P. J. Scharow.†

The Russian petroleum statistics of 1880 to 1902 have been published.‡ During that period the production increased from 400,237 tons to 10,550,745 tons.

XVII.—*SOUTH AMERICA.*

Mineral Statistics of Peru.—The fourteenth bulletin issued by the Corps of Mining Engineers of Peru deals with the mineral statistics of the republic for 1903. The pamphlet covers 45 pages, and is edited by J. A. Loredo.§ Details are given of all the mining concessions and statistics of production of gold, silver, copper, lead, borates, petroleum, and salt are given in separate chapters. It is to be hoped that in future issues it will be found possible to give statistics of the production of coal and other minerals raised in small quantities for local consumption. The production of petroleum amounted to 11,639 tons.

Iron Trade of Chili.—An elaborate report has been issued by J. Delaunay ‖ on the metallurgy of iron in Chili. There are, he shows, abundant supplies of rich ore conveniently situated, as well as of coal, wood, limestone, and refractory materials. An article has also been published ¶ on the industrial future of Chili, in which it is

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* *Gornosavodsky Listok*, July 17, 1904.

† *Zeitschrift für praktische Geologie*, vol. xii. pp. 263–267.

‡ *Moniteur du Pétrole Roumain*, vol. v. p. 279.

§ *Estadistica Minera del Peru:* Lima, Minister de Fomento, 1904.

‖ *Boletin de la Sociedad Nacional de Mineraria*, vol. xvi. pp. 159–171.

¶ *Gaceta Minera de Cataluña*, June 20, 1904.

stated that the coal mines of Lota and Coronel produce 1,000,000 tons annually and afford employment to 9000 workmen.

Mining Industry of Venezuela.—A summary of the Venezuela mining code of 1904 has been published.*

XVIII.—*SPAIN.*

Mineral Statistics.—The mineral production of Spain in 1903 † included, in metric tons, iron ore 8,304,153, and coal 2,587,652. Of manufactured products the output included, in tons, pig iron 302,657, briquettes 322,978, coke 433,780.

The exports from Bilbao during the first half of 1904 ‡ comprised 1,826,616 tons of iron ore and 17,150 tons of iron and steel.

The Spanish imports during the first half of 1904 § included 1,129,405 tons of coal, 87,087 tons of coke, 571 tons of pig iron, 2669 tons of wrought iron, and 5633 tons of steel rails. The exports included 3,642,594 tons of iron ore, and 18,843 tons of iron.

The leading clauses of the regulations relating to mining concessions are given,|| with annotations.

XIX.—*SWEDEN.*

Iron Trade Statistics.—The official statistics ¶ show that in Sweden in 1903 there were 322 iron ore mines in operation, the output comprising 3,380,700 tons of magnetite, 296,820 tons of red hæmatite and 321 tons of lake iron ore. The number of blast-furnaces in operation was 136, of Lancashire hearths 280, of Franche-Compté hearths 14, of Walloon hearths 26, of scrap smelting hearths 13, of puddling furnaces 3, of Bessemer converters 24, of open-hearth furnaces 53, of crucible steel furnaces 8, and of electric furnaces 1. The number of colliery shafts was 18, and the output of fireclay was 172,718 tons.

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* *Annales des Mines*, vol. v. pp. 702–705.

† *Mining Journal*, vol. lxxvi. p. 462; *Moniteur des Intérêts Matériels*, vol. liv. p. 2521.

‡ *Boletin Minero*, vol. vii. p. 321.

§ *Revista Minera*, vol. lv. p. 417.

|| *Revue Universelle des Mines*, vol. vi. pp. 292–313.

¶ *Kommerskollegii Underdåniga Berättelse*, Stockholm, 1904.

An historical and statistical handbook * dealing with the industrial conditions of Sweden has been published by order of the Swedish government. It is edited by G. Sundbärg, and covers 1142 pages. The sections dealing with iron mines and the iron and steel industry are based on information collected by O. G. Nordenström and J. G. Wiborgh.

The export of Swedish iron ore is steadily increasing. During the first half of 1904 the exports were 1,204,673 tons, as against 940,306 tons in the corresponding period of 1903.†

J. H. L. Vogt ‡ observes that the present most important iron ore exporting district of Sweden is that of Grängesberg, the annual exports from which amount to from 550,000 to 600,000 tons, Gellivare with an export of about 1,000,000 tons, and Kiiruna-Luossavaara with an export of some 1,200,000 tons. Basic ore forms the chief portion of this, and the whole is smelted in foreign countries. In Norway large deposits, though poorer, are known in Dunderland, near the Arctic Circle, and in South Varanger. The Dunderland deposits are about to be mined on such an extensive scale that it is anticipated that the exports of iron ore from this district in 1905 or 1906 will be as much as 750,000 tons. The ores as mined contain from 38 to 40 per cent. of iron, but this is to be enriched by Edison magnetic separators to 67 or 68 per cent., while the phosphorus contents are expected to fall as low as 0·025 per cent. The exports of ore from the Swedish and Norwegian ports have rapidly increased, due in part in the year 1903 to the first export of ore having taken place from the Kiiruna ore field. Formerly the Spanish ore occupied the chief place in the world's market, but this ore averages only 50 per cent., while that from Sweden and Norway contains as much as 63 per cent. of iron.

XX.—*TRANSVAAL COLONY.*

Coal.—The report of the Chamber of Mines shows that in 1903 there were 24 collieries at work in the Transvaal, the total output being 2,258,284 tons in the Boksburg district. The largest operations were those in the Transvaal Coal Trust, which produced 249,617 tons

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* *Sweden: Its People and its Industry.* Stockholm, 1904.

† *Affarsvärlden*, vol. iv. p. 949.

‡ *Ibid.*, May 20, 1904.

at Brakpan and 102,350 tons at Springs colliery. The Clydesdale Company produced 218,430 tons in the Middelburg district. The Transvaal and Delagoa Bay reported 378,281 tons, and the Whitbank colliery 325,319 tons.

XXI.—*TURKEY.*

Iron Imports.— According to a German consular report * the imports of iron and iron wares into Turkey from the United Kingdom has steadily diminished. On the other hand those from Germany have rapidly increased, though of late these have again diminished. They were as follows in the years stated, the similar Belgian figures being also shown :—

Years.	From Germany.	From Belgium.
	Metric Tons.	Metric Tons.
1898	8,725	23,171
1899	5,493	13,972
1900	10,091	10,095
1901	27,147	18,494
1902	21,319	17,916

As regards steel the most important import is the so-called Milanese steel imports in boxes of from 110 to 150 lbs. in weight. These come almost entirely from Austria, and in 1903 about 10,000 such boxes were imported, valued at about £8000. The imports of Swedish charcoal iron have long remained steady, showing little fluctuation.

XXII.—*UNITED STATES.*

Iron Trade Statistics.—Complete statistics of the iron and steel industries of the United States for 1903 have been issued by J. M. Swank.† The total production included, in tons, pig iron 18,009,252, Bessemer steel ingots 8,592,829, and open hearth ingots 5,829,911.

Returns collected by J. M. Swank ‡ shows that during the first half of 1904 the production of pig iron in the United States was 8,173,438 tons.

The American Iron and Steel Association has issued a thoroughly

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* *Stahl und Eisen*, vol. xxiv. p. 859.

† *Annual Statistical Report of the American Iron and Steel Association*. Philadelphia, 1904.

‡ *Bulletin of the American Iron and Steel Association*, vol. xxxviii. p. 109.

revised description of the blast-furnaces, rolling-mills, steel works and forges and bloomaries in the United States, the information contained in this edition of the Directory being brought down to the latest possible date prior to its publication.* The general plan of compilation adopted in the preparation of the Directory for 1901 has been followed by J. M. Swank in the present edition, but the inquiries submitted to the manufacturers have been more comprehensive. Whenever possible the history of each plant has been preserved, giving the date of its erection, with all subsequent additions to the plant, changes in ownership, if any, &c. In many instances the equipment of the plants has also been more fully described than in previous editions, and more attention has been given to the organisation of companies, including capitalisation and list of officers. An exact system of cross references, adopted in previous editions, shows the relation of each plant to other plants under the same ownership, but this feature has been enlarged in the present edition. The alphabetical arrangement of previous editions is retained.

Part I. of the present edition, occupying 188 pages, embraces descriptions of the United States Steel Corporation and of the operating companies and all the properties that are under its control; also of all the independent companies whose capitalisation, lists of officers, &c., as well as the descriptions of their plants, often very elaborate, are naturally looked for in a prominent part of a volume of the scope of the Directory. The descriptions in this division of the Directory embrace coal and iron ore mines, coking plants, limestone quarries, railroads, lake vessels, &c., as well as the blast-furnaces, rolling mills, and steel works. All the properties of the United States Shipbuilding Company are described.

Part II., occupying 186 pages, embodies a description of all iron and steel works in the United States that are not described in Part I., and it also gives the name and address of every company which manufactures iron or steel that is described in Part I., thus presenting a continuous and complete list of all the iron and steel works in the country. In Part II. the arrangement is by States and districts, as in the edition for 1901, blast-furnaces coming first, followed by rolling mills and steel works and forges and bloomaries. Part II. also contains a list of recently abandoned or dismantled iron and steel works and of long inactive plants.

Part III., occupying 66 pages, classifies the leading products of the rolling mills and steel works, the arrangement being by States. It

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* August 1904.

includes the Bessemer steel works, the open-hearth steel works, the crucible steel works, the steel casting works, the rail mills, the structural mills, the wire-rod mills, the skelp mills, the plate and sheet mills, the black plate mills, and the tinplate and terne plate works.

Part IV., occupying 28 pages, contains information concerning changes in offices, ownership of plants, &c., that occurred while the main part of the Directory was passing through the press; also the index to the Directory.

This edition of the Directory, which embraces 484 pages including the index, does not contain some classified lists of minor iron and steel products and of iron and steel consumers that may be found in previous editions.

Iron Ore.—The official statistics [*] show that the production of iron ore in the United States in 1903 amounted to 35,019,308 tons, or 1·5 per cent. less than in 1902, when the highest output was recorded. Of the total the Mesabi range produced 13,452,812 tons, the whole of the Lake Superior region producing 26,573,271 tons. The output of concentrated ore in 1903 was 259,469 tons, most of which was magnetically separated, the remainder having been passed through jigs. The statistics were compiled by J. Birkinbine.

The geographical distribution of iron ore in the United States is discussed by F. L. Ransome.[†]

Coal.—Returns made to the United States Geological Survey show that the United States has exceeded all previous records in the production of coal. The forthcoming report on the country's coal production, which E. W. Parker will make, will show that the total output of the coal mines of this country in 1903 amounted to 320,911,885 tons. This is an increase of 19 per cent. over the production of 1902. Of the total production 66,351,713 tons represent Pennslyvania anthracite. This is in contrast to the production of 1902, when the output was curtailed by the prolonged strike in the anthracite regions, and reached only 36,940,710 tons. The production of bituminous coal, which includes lignite, or brown coal, semi-anthracite, semi-bituminous, and cannel coal, amounted to 254,560,171 tons, valued at $354,154,285, which shows an increase of 9 per cent. in quantity.[‡]

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[*] *Mineral Resources of the United States*, Washington, 1904; *Bradstreet's*, vol. xxxii. p. 590; *Iron Age*, August 11, 1904, p. 6.

[†] *Mining Magazine*, vol. x. pp. 7-14.

[‡] *Bulletin of the American Iron and Steel Association*, vol. xxxviii. p. 118.

The commercial divisions of the competitive coal markets of the United States are described by H. S. Fleming.*

B. Simmersbach † submits statistics showing the cost of production of coal in Pennsylvania.

Petroleum.—The production of petroleum during 1903 amounted to 100,461,337 barrels, which is a larger amount than was produced in any previous year, and more than in 1902 by 11,694,421 barrels. The greatest increase in 1903 was in California, which produced nearly one-fourth of the total. The value of the entire production amounted to $94,694,050, which is an increase of 33 per cent. on that of the previous year. The average price per barrel in 1903 was $0·95 as against $0·80 in 1902.

Natural Gas. The annual production in the United States ‡ in 1903 constituted a record, having amounted to 238,769,067,000 cubic feet, at atmospheric pressure and density. The weight was 5,968,725 tons, and its heating value equal to that of 11,938,453 tons of bituminous coal. The value of the gas was $35,815,360, which is an increase of 16 per cent. as compared with the value of the gas produced in 1902. The increase in Pennsylvania and in Ohio was particularly marked.

Fluorspar.—According to a census report § on the fluorspar industry of the United States, the quantity of fluorspar produced in 1902 was 48,818 tons, valued at $275,682 as compared with 9500 tons, valued at $45,855 in the year 1889, the first census year in which statistics of the production of this mineral were collected.

In the fluorspar deposits of Illinois and Kentucky there is known to be a very large supply of this mineral, capable of meeting the demand for many years. As this overcomes one of the objections often advanced against using fluorspar in the smelting of iron—namely, that a constant supply of this mineral could not be depended upon—its use for this purpose should now increase rapidly.

The St. Louis Exhibition.—The St. Louis Exhibition is described ‖ and illustrated in numerous articles in the technical journals. The

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* *Mining Magazine*, vol. x. pp. 31–39.

† *Glückauf*, vol. xl. pp. 1055–1057.

‡ *The Production of Natural Gas*, 1903. *Report of the United States Geological Survey.*

§ *Iron Age*, August 11, 1904, p. 7.

‖ *Stahl und Eisen*, vol. xxiv. pp. 433–435, with four illustrations in the text, and one plate.

metallurgical exhibits have been described by H. Bauerman in this volume, by W. F. Reid * and also by A. Lukaszewski.†

XXIII.—*COMPARATIVE TABLES.*

The World's Production of Coal and Iron.—For purposes of comparison the following summary of the production of coal in the principal countries of the world is appended:—

Country.	Year.	Production in Tons.
United Kingdom	1903	230,334,469
Australasia—		
New South Wales	1903	6,354,846
New Zealand	1903	1,420,193
Queensland	1902	501,531
Tasmania	1903	49,069
Victoria	1903	69,861
Western Australia	1902	140,884
Austria, coal	1903	11,498,111
„ lignite	1903	22,157,521
Hungary, coal	1902	1,098,926
„ lignite	1902	5,103,236
Belgium	1903	23,913,240
Borneo	1902	50,000
Bosnia	1903	467,962
Canada	1903	7,139,852
Cape Colony	1902	168,214
Chili	1903	1,000,000
China	1902	500,000
France	1903	35,002,992
Germany, coal	1903	116,637,765
„ lignite	1903	45,819,488
Greece	1903	10,700
Holland	1902	399,133
India	1903	7,438,386
Italy, lignite	1903	346,887
Japan	1903	9,000,000
Mexico	1902	759,634
Natal	1903	713,548
Peru	1901	45,000
Portugal, anthracite	1902	16,792
Roumania, lignite	1901	105,000
Russia	1902	15,508,924
Servia	1902	153,754
Spain	1903	2,587,652
Sumatra	1902	198,581
Sweden	1903	320,390
Transvaal Colony	1903	2,258,284
Turkey	1901	200,000
United States	1903	319,068,229

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* *Journal of the Society of Arts*, vol. liii. pp. 60–73.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. lii. pp. 457–459.

A similar summary showing the production of pig iron is as follows:—

Country.	Year.	Production in Tons.
United Kingdom	1903	8,935,063
Austria	1903	970,832
Hungary	1902	425,403
Belgium	1903	1,216,500
Bosnia	1903	39,833
Canada	1903	265,418
France	1903	2,825,668
Germany and Luxemburg	1903	10,017,901
Italy	1903	75,279
Japan	1902	55,171
Russia	1902	2,592,982
Spain	1903	302,657
Sweden	1903	506,825
United States	1903	18,009,252

B. Neumann* gives an account of the iron trade in 1903, with statistics of production in the different countries. The world's production of pig iron is given as 40,889,358 tons in 1901, 44,488,230 tons in 1902, and 46,830,000 tons in 1903.

Statistics of the world's coal and iron production are given in the annual report of the Dortmund Mining Association.† The world's coal production is given as 875,000,000 tons in 1903, of which more than a third was raised in the United States, fully a quarter in Great Britain, and nearly a third in Germany.

The tenth number of a publication ‡ annually prepared in the Commercial, Labour, and Statistical Department of the Board of Trade, has been issued showing the production and consumption of coal in the principal countries of the world during each of the years from 1883 up to 1903, or the most recent year for which the figures were available. In addition to statistics of production and consumption, particulars are also given of the average value per ton at the collieries, the number of persons employed in coal-mining, coal imports and exports, &c., and statistics of lignite production and petroleum production in certain countries are also contained in the return.

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* *Glückauf*, vol. xl. pp. 1048–1055.

† *Jahresbericht des Vereins für die bergbaulichen Interessen im Oberbergamtsbezirk Dortmund:* Essen, 1904.

‡ *Coal Tables*, 1903 [205]; price 5½d.

The World's Production of Steel.—For purposes of comparison the following estimate by J. M. Swank * of the world's production of steel ingots in 1903 is appended:—

	Tons.	Percentage.
United States	14,534,978	40·93
Germany	8,801,515	24·79
Great Britain	5,134,101	14·46
Russia	2,118,971	5·97
Austria-Hungary	1,190,000	3·35
France	1,905,000	5·36
Belgium	981,740	2·76
Sweden	318,897	0·90
Canada	181,514	0·56
Spain	199,642	0·31
Italy	108,864	0·51
Other countries	34,778	0·10
	35,510,000	100·00

Of the United States steel outturn 63·5 per cent. was produced by the Steel Corporation. In Germany over 90 per cent. of the production is made by the basic process.

In Germany 8,188,116 tons of basic steel were made in 1903. In the United States in 1903 the production of basic open-hearth steel ingots was 4,734,913 tons. Whilst there was a decrease of over 8 per cent. in the production of acid steel, there was, compared with 1902, an increase of 5·3 per cent. in the production of basic steel. No basic Bessemer steel ingots were made. In the United Kingdom 668,399 tons of basic Bessemer and 406,780 tons of basic open-hearth steel were made. In 1902 in Belgium 725,000 tons of basic steel were made. In France the statistics for 1903 are not yet available, but the production of basic steel in 1902 was nearly half the total production. In Canada the production of basic steel in 1903 was 181,000 tons.

Progress of the World's Iron Trade.—In a paper read before the *Verein deutscher Eisenhüttenleute*, E. Schrödter † gives a valuable summary of the progress that has been made in the various branches of the world's iron trade during the last twenty-five years, and then deals in particular with the progress made in the German section of the industry during that period. The rapid progress that has been made by the United States and by Germany, is made strikingly

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* *Annual Statistical Report of the American Iron and Steel Association*, p. 94. Philadelphia, 1904.

† *Stahl und Eisen*, vol. xxiv. pp. 490–500.

evident by the diagrammatic representations of the various outputs which are given. The first of these deals with the output of pig iron. This was as follows in the year mentioned, in metric tons:—

Year.	United Kingdom.	United States.	Germany.	France.	Russia.
1879 . . .	6,093,060	2,786,650	2,226,587	1,400,286	432,997
1890 . . .	8,033,052	9,353,020	4,658,451	1,962,196	927,585
1900 . . .	9,003,046	14,009,870	8,520,540	2,714,298	2,897,636
1903 . . .	8,952,183	18,297,400	10,017,901	2,827,668	——

In 1879 Austria-Hungary made 404,162 tons of pig iron, and in 1903 1,500,000.

The next diagram deals with the production of steel, and shows this to have been as follows, again in metric tons:—

Year.	United Kingdom.	United States.	Germany.	France.	Russia.
1879 . . .	1,029,522	950,550	478,344	333,265	233,471
1890 . . .	3,637,381	4,346,932	1,613,783	581,998	378,424
1900 . . .	5,130,800	10,382,069	6,645,869	1,565,164	1,830,260
1903 . . .	5,114,646	(15,186,406 in 1902)	8,801,515	1,854,620	——

In 1879 Austria-Hungary made 124,888 tons of steel, and in 1902 1,143,900 tons.

The author deals with the changes in processes introduced during the period under review, and also with the cost of production.

A third diagram shows the production and consumption of iron in Germany during the same period, and a fourth the exports of iron and iron manufactures, exclusive of machinery. This was as follows:—

Year.	United Kingdom.	United States.	Germany.
	Metric Tons.	Metric Tons.	Metric Tons.
1880 . . .	3,787,271	3,609	881,748
1890 . . .	4,001,430	46,423	950,739
1900 . . .	3,540,680	1,040,103	1,548,558
1903 . . .	3,571,373	331,606	3,479,999

An exhaustive article on the position of the German iron industry in the world's markets has been written by A. Weiskopf.*

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* *Zeitschrift für angewandte Chemie*, vol. xvii., Nos. 35 and 36.

E. de Billy and J. Milius* in the course of an article on the competition prevailing in the world's iron and steel industries, give a number of tables relating to production and consumption in all countries during the past seven years.

The following figures are given † showing the population, and consumption of pig iron per inhabitant in 1903:—

	Population.	Consumption. Lb.
United States	80,047,000	499
Germany	58,549,000	380
Great Britain	41,961,000	470
France	38,962,000	160
Russia	141,000,000	39
Austria-Hungary . . .	45,405,000	69
Belgium	6,694,000	401
Sweden	5,199,000	208
Spain	18,618,000	41
Canada	5,457,000	109
Italy	32,475,000	2
Japan	45,862,000	1
Total . . .	1,509,134,000	68

Jüngst ‡ discusses the international competition in iron and steel.

The World's Production of Manganese Ore.—J. Birkinbine § estimates that the world's production of manganese ore in 1903, in tons, was as follows: Russia, 884,200; India, 165,006; Brazil, 156,269; Spain, 55,540; Turkey, 49,100; Germany, 47,994; Cuba, 18,795; Japan, 16,298; Greece, 14,962; Chili, 12,990; France, 12,536; Hungary, 12,490; Austria, 6179; Queensland, 4600; Bosnia, 4537; United States, 2825; Italy, 2477; Sweden, 2244; Java, 1388; Portugal, 904; Canada, 135; and South Australia, 18.

The World's Railways.—The length of the world's railways at the end of 1902 amounted to 838,216 kilometres, as compared with 816,755 kilometres at the close of the preceding year. Full details are given for the different countries.||

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* *Revue de Métallurgie*, pp. 104–133, 226–240.

† *Iron Age*, June 23, 1904, p. 38.

‡ *Glückauf*, vol. xl. pp. 726–736.

§ *Mineral Resources of the United States*, Washington, 1904.

|| *Stahl und Eisen*, vol. xxiv. pp. 847–850.

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"*Addressbuch sämtlicher Bergwerke Hütten- und Walzwerke Deutschlands.*" 8vo, pp. 239. Dresden: H. Kramer. (Price 3s.)

AMERICAN IRON AND STEEL ASSOCIATION. "*Annual Statistical Report of American and Foreign Iron Trades for* 1903." 8vo, pp. 94. Philadelphia.

ANDERSON, W. C. "*The Chemistry of Coke.*" 2nd edition, 8vo. Glasgow and Edinburgh: Hodge & Co. (Price 5s. net.)

ATTWOOD, E. L. "*A Text-book on the Construction and the Protection of War Vessels.*" 8vo, pp. 300, with 209 illustrations. London: Longmans, Green & Co. (Price 10s. 6d. net.)

BAUM, G. "*Die Verwertung des Koksofengases.*" 8vo, pp. 124. Berlin: J. Springer. (Price 4s.)

BISCHOF, C. "*Die feuerfesten Tone.*" 3rd edition. 8vo, with 90 illustrations. Leipzig. (Price 12s.)

BJÖRLING, P. R. "*Briquettes and Patent Fuel. Their Manufacture and Machinery Connected Therewith.*" Pp. 256. Illustrated. London: Ribman, Ltd. (Price 15s.)

BORCHERS, W. "*Electric Smelting and Refining.*" Translated from the 3rd German edition by W. G. McMillan. 8vo, with illustrations. London: Charles Griffin & Co., Ltd. (Price 21s. net.)

BUHLE, M. "*Technische Hülfsmittel zur Beförderung und Lagerung von Sammelkörpern.*" Part II. 8vo, pp. 204, with 551 illustrations and 8 plates. Berlin: J. Springer. (Price 20s.)

BÜRGEL, H. G. M. "*Führer durch die Maschinen- Eisen- und Metallindustrien Deutschlands.*" 8vo. Berlin. (Price 3s.)

"*Directory to the Iron and Steel Works of the United States.*" Published August 25, 1904. Embracing a full list of the blast-furnaces, rolling-mills, steel works, steel casting works, tinplate works, rail mills, structural mills, plate and sheet mills, and forges and bloomaries in the United States, &c., &c. Sixteenth edition, corrected to August 1, 1904. 8vo, pp. 484. Philadelphia. (Price 10 dollars.)

DOSCH, A. "*Wert und Bestimmung des Kohlensäuregehaltes der Heizgase.*" 8vo. Berlin: R. Dietze. (Price 3s.)

Donath, E. "*Der Graphit.*" 8vo, pp. 175, with 27 illustrations. Vienna: F. Deuticke. (Price 6s.)

Douglas, J. "*Untechnical Addresses on Technical Subjects.*" 8vo, pp. 84. New York: John Wiley & Sons. (Price 1 dollar.)

[The three addresses contained in this volume are: (1) The conditions of the technical progress of the 19th century; (2) The development of American mining and metallurgy; and (3) The equipment of a training school in mining and metallurgy.]

Duhem, P. "*Thermodynamics and Chemistry.*" Translated by G. K. Burgess. New York: John Wiley.

"*Engineering Standards Committee. British Standard Specifications and Sections of Bull-headed Railway Rails.*" Folio, pp. 12, with 12 plates. London: Crosby Lockwood & Son. (Price 10s. 6d. net.)

"*Engineering Standards Committee. British Standard Specification for Tubular Tramway Poles.*" Folio, pp. 6. London: Crosby Lockwood & Son. (Price 5s. net.)

"*Engineering Standards Committee. British Standard Specifications of Copper Conductors and the Thickness of Dielectric.*" Folio, pp. 10. London: Crosby Lockwood & Son. (Price 2s. 6d. net.)

Gerdien, H. "*Einfluss der Torsion auf das magnetische Moment zirkular magnetisierter Nickel- und Eisendrähte.*" 8vo. Göttingen: Vandenhoeck and Ruprecht. (Price 2s. 5d.)

Goodchild, G. F., and C. F. Tweney. "*Technological and Scientific Dictionary.*" London: George Newnes. (Price 1s. net each part.)

Guillet, L. "*L'Étude théorique des Alliages métalliques.*" 8vo, pp. 232, with 117 illustrations. Paris: Dunod. (Price 7½ francs.)

[The subjects dealt with are the phase law, melting curves, cooling curves, microscopic metallography, physical and mechanical properties.]

Guillet, L. "*Les Aciers spéciaux.*" 4to. Paris: Dunod. (Price 10 francs.)

Hagn, H. "*Schutz von Eisenkonstruktionen gegen Feuer.*" 8vo, with 163 illustrations. Berlin: J. Springer. (Price 2s.)

Heinzerling, F. and O. Intze. "*Deutsches Normalprofil-Buch für Walzeisen.*" Part I. 6th Edition. With illustrations and 18 plates of standard sections of rolled iron for structural work. Aachen. (Price 7s. 6d.)

Hime, H. "*Gunpowder and Ammunition; Their Origin and Progress.*" 8vo. London: Longmans, Green & Co. (Price 9s. net.)

Holmes, A. C. "*Practical Shipbuilding. A Treatise on the Structural Design and Building of Modern Steel Vessels.*" With Atlas. (Price 48s.)

Jeans, J. S. "*Canada's Resources and Possibilities.*" London: British Iron Trade Association. (Price 12s. 6d.)

Jüptner, H. von. "*Eléments de Sidérologie.*" Translated into French by E. Poncelet and A. Delmer. Part I. 8vo, pp. 341, with 81 illustrations. Paris: Béranger. (Price 18 francs.)

Jüptner, H. von. "*Grundzüge der Siderologie.*" Part III., Section I. 8vo, pp. 152, with 19 plates and 3 figures. Leipzig: A. Felix. (Price 6s. 6d.)

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Kennedy, R. "*Modern Engines and Power Generators.*" 4to, Vol. I., pp. 216; Vol. II., pp. 215; Vol. III., pp. 213. London: Caxton Publishing Co. (Price 9s. per vol.)

Marsh, C. F. "*Reinforced Concrete.*" 8vo, pp. 545, with 512 illustrations. New York: D. van Nostrand Co. (Price 7 dollars.)

Martens, A. "*Traité des Essais des Matériaux Destinés à la Construction des Machines.*" Translated by P. Breuil. Vol. I., 8vo, pp. 671, with 558 figures; Vol. II., Atlas, with 31 plates. Paris: Gauthier-Villars. (Price 42s.)

Martens, A., and M. Guth. "*Das königliche Materialprüfungsamt zu Gross-Lichterfelde-West.*" 8vo, pp. 380, with 5 plates, frontispiece, and 359 figures in the text. Berlin: J. Springer. (Price 10s.)

Martin, R. "*Die Eisenindustrie in ihrem Kampf um den Absatzmarkt.*" 8vo, pp. 332. Leipzig: Duncker & Humblot. (Price 7s.)

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